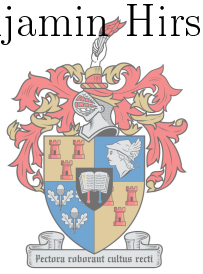
The Development of a Policy Framework for Integrating Smart Asset Management Within Operating Theatres in a Private Healthcare Group to Mitigate Critical System Failure

by

Charles Benjamin Hirschowitz Nel



Thesis presented in fulfilment of the requirements for the degree of Master of Engineering (Engineering Management) in the Faculty of Engineering at Stellenbosch University

Supervisor: **Dr J.L. Jooste**

March 2018

Declaration

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Abstract

The Development of a Policy Framework for Integrating Smart Asset Management Within Operating Theatres in a Private Healthcare Group to Mitigate Critical System Failure

C. B. H. Nel

Thesis: MEng (Industrial)

March 2018

According to the World Health Organisation (WHO), health technologies are an essential basis for the correct functionality of an effective healthcare system. It is within this hospital environment that medical equipment is considered hospital assets that can directly affect human lives. However hospitals within the private healthcare industry are also considered businesses which apart from dealing with human lives, are also accountable to management to be profitable, where assets are also considerable investments and maintenance costs need to be factored into the return of asset investment as well as income generated from asset utilisation and performance. It is therefore important to have a well planned and managed physical asset management (PAM) programme that is able to keep the medical equipment in a healthcare institution reliable, safe and available for use when it is needed. This thesis has narrowed down the strategic execution of PAM to an operating theatre as a critical asset, both in terms of human safety and also operational importance. By utilising a case study approach to qualitatively explore the implementation of PAM, a new concept known as Smart Asset Management (SAM) has been identified as a means to assist physical asset management strategic execution (PAMSE).

SAM is a new expression where the term *smart*, is a concept used increasingly within the commercial environment, which relates to a perception of technological intelligence. The concept of the Internet of Things (IoT) has also become a reality which necessitates the need for a different approach to managing physical assets. With this emergence of technological intelligence, comes the possibility of vast quantities of asset data and the analysis thereof which has proven to add value to asset management. In order to capitalise

and expand on this value creation, SAM came into being by incorporating proven methodologies and applying these within real-time management structures.This thesis also sets out to create industry awareness about the business potential of incorporating SAM within automated asset environments for assisting in strategic management decisions. In order to do so, SAM applications are investigated, as well as requirements and benefits of SAM implementation according to various literature sources. By investigating concepts such as; performance management (PM) and condition monitoring (CM), in conjunction with SAM; this thesis aims to illustrate how SAM can be incorporated within the strategic execution of PAM to predict and avoid critical system failure.

Considering the qualitative intricacies of this investigation, it was identified that management at various levels need to be engaged as well as informed with regards to the context in which SAM can be utilised to address potential risks. Ultimately the case study approach was adopted to portray a common understanding experienced by technical managers operating within various hospitals across South Africa. Hence by providing a view of an ideal, integrated holistic system, the concept of SAM implementation will be presented to various participants within the same corporate group. In accordance with the face validation approach, the feedback and experiences gained from professionals within the industry are further consolidated within a model which represents the best practices towards utilising SAM within the given constraints. In order to further validate this conceptual implementation of SAM, the face validation analyses are further utilised to facilitate expert agreement of the proposed SAM concept. The developed theory is further summarised and consolidated into a theoretical guideline for senior management to improve PAM and the execution thereof. Finally the model therefore serves the purpose of assisting senior management to steer their focus and efforts towards practises that contribute towards strategic execution which assists in risk mitigation planning associated with critical asset failure.

Uittreksel

Die Ontwikkeling van 'n Beleidsraamwerk om Slim Batebestuur, Binne Operasieteaters in die Privaat Gesondheidsorggroep te Integreer, om Sodoende Kritiese Stelselmislukkings te Verlig

("The Development of a Policy Framework for Integrating Smart Asset Management Within Operating Theatres in a Private Healthcare Group to Mitigate Critical System Failure")

C. B. H. Nel

Tesis: MIng (Bedryfs)

Maart 2018

Volgens die Wêreld Gesondheidsorganisasie (WGO) vorm gesondheidstegnologieë 'n essensiële basis vir gesondheidsorgsisteme om effektief en reg te kan funksioneer. Dit is binne die hospitaalomgewing waar mediese toerusting as mediese bates, wat mense se lewens direk beïnvloed, beskou kan word. Hospitale, binne die privaat gesondheidsektor, word egter as besighede beskou waar hierdie hospitale, buiten die verantwoordelikheid vir mense se lewens, ook aanspreeklik gehou word vir bestuur om winsgewend te wees waar bates ook as beleggings beskou word. Onderhoudskostes moet vanuit bate-beleggings, sowel as die inkomste van bates en optrede, gegenereer word. Dit is daarom van kardinale belang om 'n goeie beplande en bestuurde Fisiese Batebestuur (FBB) program in te stel wat sal kan bybly met mediese toerusting in 'n gesondheidsorg-instituut wat betroubaar, veilig en beskikbaar is indien nodig. Hierdie tesis beskryf die strategiese uitvoering van FBB in operasie-teaters as 'n baie belangrike bate, biede in terme van menslike veiligheid asook van operasionele belang. Deur middel van 'n gevallestudie-benadering sal die implementering van FFB op 'n kwalitatiewe wyse ondersoek word. 'n Nuwe konsep, bekend as Slim Batebestuur (SBB) is geïdentifiseer om te help dat Fisiese Batebestuur Strategiese Uitvoering (FBBSU) suksesvol geskied.

SBB is 'n nuwe uitdrukking waar die woord, Slim, al hoe meer in die korporatiewe wêreld gebruik word, wat met die persepsie van tegnologiese intelligensie

verband hou. Die idee van die Internet van Dinge (IvD) het ook 'n realiteit begin word wat die noodsaaklikheid vir 'n verskillende benadering tot fisiese batebestuur, beklemtoon. Met die ontstaan van tegnologiese intelligensie, het die moontlikhede van veelomvattende kwantiteite van batebestuur en die analisering daarvan ontstaan, wat reeds bewys het om waarde tot batebestuur te voeg. Om hierdie waardeskepping te kan kapitaliseer en uit te brei, is SBB geskep deur reeds bewysde metodes te kan inkorporeer en om dit binne werklike tydsbestuur-strukture toe te pas. Hierdie tesis poog daarin om die industrieÃ« bewus te maak van die besigheidsvoordeel om SBB binne automatiese bate-omgewings te inkorporeer om sodoende met strategiese bestuursbesluite te help. Deur dit te kan doen, moet SBB toepassings, sowel as die vereistes en voordele vir die implementering van SBB, deur middel van verskeie literatuurbronne, ondersoek word. Die ondersoek van konsepte soos Prestasiebestuur (PB) en Toestandmonitering (TM), in samewerking met SBB, streef hierdie tesis daarin om te illustreer hoe SBB, binne die strategiese uitvoering van FBB opgeneem kan word om sodoende kritiese stelselmislukkings te voorspel en te vermy.

Te wete van die kwalitatiewe ingewikkeldheid van hierdie ondersoek, is daar geïdentifiseer dat Bestuur op verskillende vlakke betrek en ingelig moet word, rakende die konteks waarin SBB gebruik kan word om sodoende potensiële risiko's aan te spreek. Die uiteinde van hierdie studie maak van 'n Gevallestudiebenadering gebruik om die algemene begrip van tegniese bestuurders, van verskeie hospitale regoor Suid-Afrika, te versamel en verder uit te beeld. Deur middel van 'n ideale, geïntegreerde en holistiese stelsel, sal die konsep van SBB-implementering aan verskeie deelnemers, binne dieselfde korporatiewe groep, blootgestel kan word. Ooreenstemming is bewerkstellig deur gebruik te maak van die gesigvalideringsbenadering, waar terugvoer en ervarings van professionele beroepspelers, binne die industrie, versterk is deur middel van 'n model, wat die beste praktyke verteenwoordig, om SBB binne die gegewe beperkings te implementeer. Die gesigvalideringsanalise is verder benut om die geldigheid van hierdie konseptuele implementering van SBB te bewys deur die ooreenstemming van kenners vir die voorgestelde SBB-konsep, te fasiliteer. Die Ontwikkelingsteorie is verder opgesom en verstewig deur middel van 'n teoretiese riglyn wat vir Seniorbestuur sal help om FBB, en die uitvoering daarvan, verder te verbeter. Die model het op die ou einde ten doel om Seniorbestuur by te staan met hul fokus en pogings op praktyke, wat tot strategiese uitvoering bydra om sodoende die vermindering van kritiese bates en risikobeperkings aan te spreek.

Acknowledgements

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- My employer, Mediclinic for their role and assistance in making this thesis possible.
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- To all my family and friends for their prayers, constant motivation and support, allowing me the time to excuse myself in order to complete my work.
- To my mother for all her love and support.
- Specifically to my father-in-law for his support and assistance in allowing me to complete my masters - “Vreeslik dankie pa!”

Dedications

This thesis is dedicated to my wife, for without her constant motivation and support other priorities would always take precedence.

"Jy is my allerliefste, my rooiborsduif
my liefde reis altyd met jou mee,
Jy moet van my liefde bly weet
soos van die vlerke waarmee dit kan vlieg.
Oneindig lief vir jou my skat!"

Modified from B. Breytenbach - Allerliefste, ek stuur vir jou 'n rooiborsduif

Papers and Publications

- "A technologically-driven asset management approach to managing physical assets – a literature review and research agenda for smart asset management"
  Nel, Charles Benjamin Hirschowitz; Jooste, Wyhan J. L. (Southern African Institute for Industrial Engineering, 2016)

Contents

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Nomenclature

List of acronyms and abbreviations

AHU: Air Handling Unit

AIS: Asset Information Strategy

AM: Asset Management

AMa: Asset Maintenance

AMaP: Asset Maintenance Plan

AMP: Asset Management Plan

ARP: Asset Responsible Person

CAQDAS: Computer Assisted Qualitative Data Analysis Software

CM: Condition Monitoring

CMMS: Computer Managed Maintenance System

DAM: Digital Asset Management

DSS: Decision Support System

GUI: Graphic User Interface

IoT: Internet of Things

IAM: Institute of Asset Management

KPIs: Key Performance Indicators

MC: Mediclinic

MCSA: Mediclinic Southern Africa

MPP: Maintenance Program Planning

MSI: Maintenance Significant Item

MTBF: Mean Time Between Failure

OEE: Overall Equipment Effectiveness

O&G: Oil and Gas

OM: Operations Management

PAM: Physical Asset Management

PAMP: Physical Asset Management Programme

PAMSE: Physical Asset Management Strategic Execution

PdM: Predictive Maintenance

PLC: Programmable Logic Controller

PM: Performance Management

RFID: Radio Frequency Identification

ROI: Return on Investment

SAM: Smart Asset Management

SAMP: Strategic Asset Management Plan

SCADA: Supervisory Control and Data Acquisition

SPC: Statistical Process Control

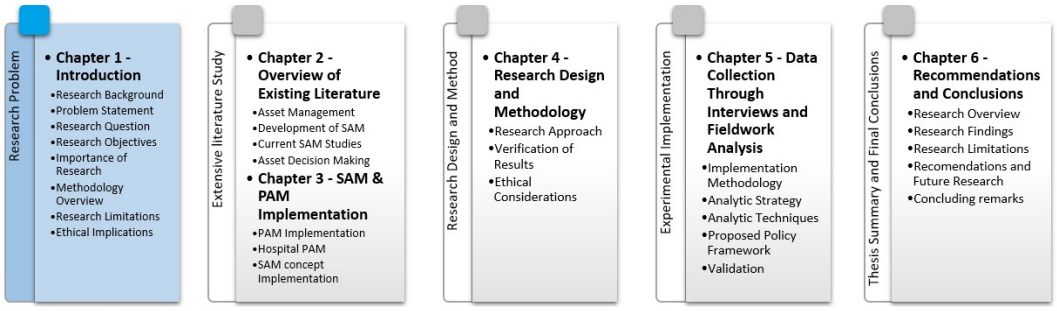
TLAM: Total Life-cycle Asset Management

TM: Technology Management

UPS: Uninterrupted Power Supply

Chapter 1

Introduction



Chapter Aims:

This chapter aims to familiarise the reader with the research agenda as well the structure and implementation procedure in which this study will be conducted. This chapter will also be used to identify the formulation of the research question and the related research objectives.

Chapter Outcomes:

- Acquaintance with the sphere of research
- Addressing the proposed research objectives
- Addressing the importance of the research agenda
- Clarification regarding the document aims and layout

1.1 Introduction

According to the World Health Organisation (WHO), health technologies are an essential basis for the correct functionality of an effective healthcare system (WHO, 2011). It is within this hospital environment that medical equipment is considered to be hospital assets that can directly affect human lives. However hospitals within the private healthcare industry are also considered to be businesses which, apart from dealing with human lives, are also accountable to corporate management to be profitable, where assets are also considerable investments and maintenance costs need to be factored into the return of asset investment as well as income generated from asset utilisation and performance. It is therefore important to have a well planned and managed physical asset management programme (PAMP) that is able to not only assist with asset maintenance, by keeping the medical equipment in a healthcare institution reliable and safe, but also to improve asset performance by keeping assets available for use when they are needed. Within this realisation, a gap has been identified by this study with regard to the management of an important asset infrastructure within the private healthcare sector, supporting operating theatres. This study aims to further explore methods of measuring asset performance through interpreting asset information to assist in managing these critical assets.

> *An effective medical equipment maintenance programme consists of adequate planning, management and implementation. Planning considers the financial, physical and human resources required to adequately implement the maintenance activities. Once the programme has been defined, financial, personnel and operational aspects are continually examined and managed to ensure the programme continues uninterrupted and improves as necessary. Ultimately, proper implementation of the programme is key to ensuring optimal equipment functionality.* (WHO, 2011)

Within this awareness of asset utilisation and availability, comes the notion of actively managing assets to improve performance. William Edwards Deming was incorrectly quoted as saying "*You can't manage what you don't measure*", when in fact he was adamant that the management of an organisation cannot be run on visible measures alone. His concerns were related to the long-term consequences which organisations are confronted with that cannot be measured in advance (Deming, 1994). It is within this awareness that the theory of Asset Management (AM) is an integral study. AM, with specific reference to governing physical equipment i.e. Physical Asset Management (PAM), has been described by the US Department of Transport (1999) as a means of planning in advance by substantiating the security of a decision on information and measurements. The justification of future strategic processes

and outcomes is therefore based on information withdrawn from physical assets in order to make these decisions. Various PAM industry standards concur with this notion endorsing the importance that asset information has and the correct implementation of PAM to further mitigate risks, improve performance opportunities and decrease operational costs (BSI, 2008; ISO55000, 2014; GFMAM, 2014; IAM, 2015). It can therefore be implied that the success of organisational strategic processes, with reference to physical equipment, is dependent on the interpretation of information collected from individual assets as well as an encompassing asset network.

Although Deming's concerns have various merits, established quality models are also used to illustrate that effective actions or decisions are based on a loop back of information, such as the Define-Measure-Analyse-Improve-Control (DMAIC) cycle and the Plan-Do-Check-Act (PDCA) cycle of which Deming was a contributor (Deming, 1994). Also within this concept of information feedback, is the inception of the IoT which is realising the accessibility of vast quantities of information from assets to various sources. This creates a requirement for a new approach to AM which can effectively utilise this information. Statistical analysis and the use of reliable figures are integral measuring tools to access quality and performance standards (IAM, 2012). These tools emphasise the need to continually monitor assets to evaluate the quality and performance of various processes to control their outcomes. The WHO also emphasise the fact that continual measurement and performance examination is required to keep a PAMP functioning efficiently. With regard to measuring performance, Performance Management (PM) is considered a separate field of study, which also highlights the integral role that asset information can play, where OM is defined as "*the process of quantifying action, where measurement is the process of quantification and action leads to performance*", consequently the management of performance can be seen as "*quantifying the efficiency and effectiveness of an action*" (Neely *et al.*, 1995). Considering the importance of PAM, Asset Management Strategy (AMS) is also a key factor to the longevity of PM, where according to IAM (2012) an

> *Asset Management Strategy is concerned with the long term strategic requirements of the physical assets. It provides direction and guidance to enable the creation of investment and maintenance plans - essential to putting in place the resources (including finance) to manage the assets consistent with achieving desired outcomes.* (IAM, 2012)

The WHO enforces this principle of implementing a strategy to reach desired outcomes, implemented through measuring asset performance.

> "*For effective management of the maintenance programme, it is important to measure performance. Most performance measures do not have a standard or benchmark to compare with. In such cases the manager should monitor performance over time, investigate any significant trends, and identify opportunities for improvement.*" (WHO, 2011)

Therefore in order to improve performance, it can be stated that organisations need to quantify action to be able to establish and realise performance. The action needs to be measured toward completion i.e. goals and benchmarks, which are realised through internalised improvements or extrospection. This can lead to achieving established end goals (WHO, 2011). The Aberdeen group is an independent organisation which identifies best practices within asset-owning organisations which rely on AM performance strategies to excel within the competitive business environment (Aberdeen, 2008). Within their research, this organisation has identified the strategic advantages achieved by organisations, referred to as best-in-class organisations, when technology is integrated into asset information feedback as well as incorporating Digital Asset Management (DAM). Aberdeen also measured the best-in-class performance as related to three Key Performance Indicators; Overall Equipment Effectiveness (OEE), operational throughput and low asset downtime. Although these KPIs as identified for a manufacturing environment, these principles can still hold true for assets within the healthcare sector considering patient safety as a non-negotiable factor. The WHO recognises the requirement of these KPIs for effective management within the healthcare industry, and addresses them further in Figure 1.1, with respect to management criteria which includes factors such as; performance management and performance improving measures (WHO, 2011).

Therefore, recognising the important role that PM, technological information feedback and more specifically the strategic management of physical assets play within the healthcare sector, these elements are factors which contribute toward identifying performance opportunities for assets to work efficiently, mitigate risks and improve asset availability (WHO, 2011). Within this realisation it is important to consider ideal practices available to implement these standards, applicable to a overhead strategic AM implementation. Hence the consideration of Smart Asset Management (SAM) has been identified as a means to improve strategic execution of PAM rooted within AM. AM as defined by the Institute of Asset Management (IAM) emphasises the notion of asset information and processing thereof to collect asset knowledge to assist in making strategic decisions (IAM, 2012). Therefore the proposed concept of SAM, discussed within this thesis, identifies a means to improve AM strategies within a private healthcare organisation, where SAM can offer a structure

Figure 1.1: Management Aspects of a Healthcare Maintenance Programme

Adapted from WHO (2011)

for validating and improving asset performance by collecting and incorporating reliable asset information within strategic business decision-making models implemented within a real-time environment.

> "*A maintenance strategy includes procedures for inspection, as well as preventive and corrective maintenance. Performance inspections ensure that equipment is operating correctly, safety inspections ensure the equipment is safe for both patients and operators, and preventive maintenance (PM) aims to extend the life of the equipment and reduce failure rates. Additionally, some hidden problems may be discovered during a scheduled inspection. However, performing inspections of equipment only ensures that the device is in good operating condition at the time of inspection and cannot eliminate the possibility of failure during future use; the nature of most electrical and mechanical components is that they can potentially fail at any time.*" (WHO, 2011)

It is with this awareness that assets within the hospital environment, more importantly those which directly impact on human lives, need to be strategically monitored and managed on a continual basis. Where PM and Condition Monitoring (CM) are tools which need to be utilised to ensure industry best practices. In order to achieve this requirement SAM can potentially play an

important role within asset owning organisations to go beyond asset maintenance and rather support PAM by utilising smart technologies to effectively collect asset information and hence better manage assets within this healthcare environment. This study sets out to further investigate these conceptual requirements of SAM implementation.

1.2 Research Background

Within a healthcare environment, the key focus is always related to patient safety (WHO, 2011). Within the private healthcare industry this requirement remains a central focus whilst also having to consider the business application in addressing satisfaction of stakeholders and clients. To elaborate further on the business case presented by private healthcare facilities the current legislation in South Africa is further addressed whilst also paying attention to the organisation in which this research study is conducted.

1.2.1 Private Healthcare in Southern Africa

The Health Systems Trust (HST) is a non-profit organisation which specialises in conducting healthcare research whilst working to strengthen ongoing development of comprehensive health systems in Southern Africa (HST, 2016). Within a research study in the private healthcare organisations, the HST has made the following observation regarding the relationship between healthcare practitioners/doctors and the private healthcare facility:

> Doctors play a central role in ensuring the success of a hospital. Decisions that determine the content of hospital care are made by doctors, making them indirect sellers of hospital services. However, doctors are also dependent on the hospital to supply a complete service to patients, thus making the relationship between private hospitals and doctors one that is mutual. In terms of the ethical rules of the Health Professions Council of South Africa (HPCSA), private hospitals are barred from appointing doctors and other health professionals, with the exception of nursing staff. Since private hospitals cannot appoint doctors directly, they adopt an approach of incentives to attract various health care professionals to establish their practices within hospital premises. Both Mediclinic and Netcare openly declare that they invest in infrastructure to enhance the satisfaction of doctors practising at their facilities. (Matsebula and Willie, 2007)

Therefore it is evident from this research article that although patients are clients of the hospital, the medical practitioners are responsible for dictating

which facility should be utilised. Hence the medical practitioner should also be considered a client of the hospital, where the facility and availability of the equipment offered are important factors when considering a competitive market environment. Providing facilities which are considered more trustworthy and dependable are key strategic factors to improve customer satisfaction.

1.2.2 Organisational Background

As highlighted within the introduction, this study is set forth in the private healthcare sector where this research study, as well as the field study is conducted within the Mediclinic private healthcare group. This section of the research will be used to elaborate on the organisational structure applicable to the group, captured in an organogram for the technical department responsible for asset maintenance. Figure 1.2 illustrates the organogram, highlighting the hierarchy of support as well as hierarchy for PAM decision-making.

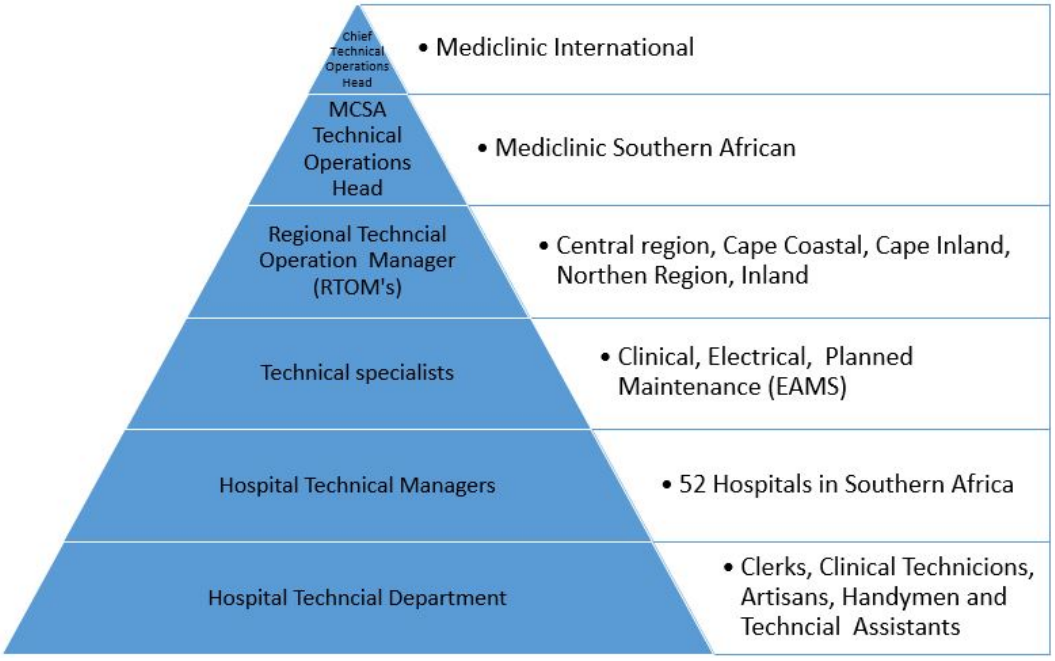


Figure 1.2: Mediclinic Southern Africa Organogram

Adapted from Mediclinic (2016)

Although Mediclinic's organisational reach stretches beyond Southern Africa, (international hospitals are located in England, Switzerland and the United Arab Emirates), this study will be focused within the Mediclinic Southern Africa (MCSA) group, where some important organisational figures related to specifically MCSA are captured in Table 1.1.

Table 1.1: MCSA Organisational Information *sourced from (Mediclinic, 2016)*

Number of Hospitals	52
Licensed Beds	8017
Number of Theatres	270
Number of employees	16832

This study therefore aims to place a particular focus on the organisational management structures which dictate as well as rationalise the participants involved within the case study research methodology as proposed in section 4. This study also aims to potentially improve the strategic management of physical assets associated to operating theatres within the group. The IAM (2014) emphasise the requirement for corporate management involvement as "The backbone to a good management system for assets is the clear connectivity between the organisation strategic plan (commonly called the business plan) and the on-the-ground daily activities (through all of the relevant connecting layers) of individual departments (planning, engineering, procurement, operations, maintenance, performance management etc)." (IAM, 2014). Where the IAM (2014) also refers to this strategic alignment as a "line of sight" due the fact that people on the front line need to have direct visibility for the reasons of their activities. Therefore it is important to have the buy-in of high-order management and operational management structures to approve the proposed SAM model.

Furthermore as illustrated in Figure 1.3, these 52 hospitals are spread out with varying distances from corporate head office (situated in Stellenbosch, Western Cape) whereas various hospitals are situated in remote destinations. This far-reaching distribution of hospitals makes strategic group management and support from the corporate office a difficult task to achieve.

It is evident from this organisational structure that the facilitation of managing technical operations at hospital level is a requirement to be determined from corporate management structures. These structures are human asset-intensive processes requiring competent staff at various levels within the organisation. Within this organisational structure it is also apparent for corporate office to manage the operational activity of various hospitals within the group, performance management based on asset performance is an integral tool to benchmark success. To establish this performance management framework, accurate information needs to be accumulated in order to establish the individual benchmarks or targets for hospitals to succeed to through utilisation of a policy framework. This process is further investigated within the problem statement, to establish the need and direction for this research agenda.

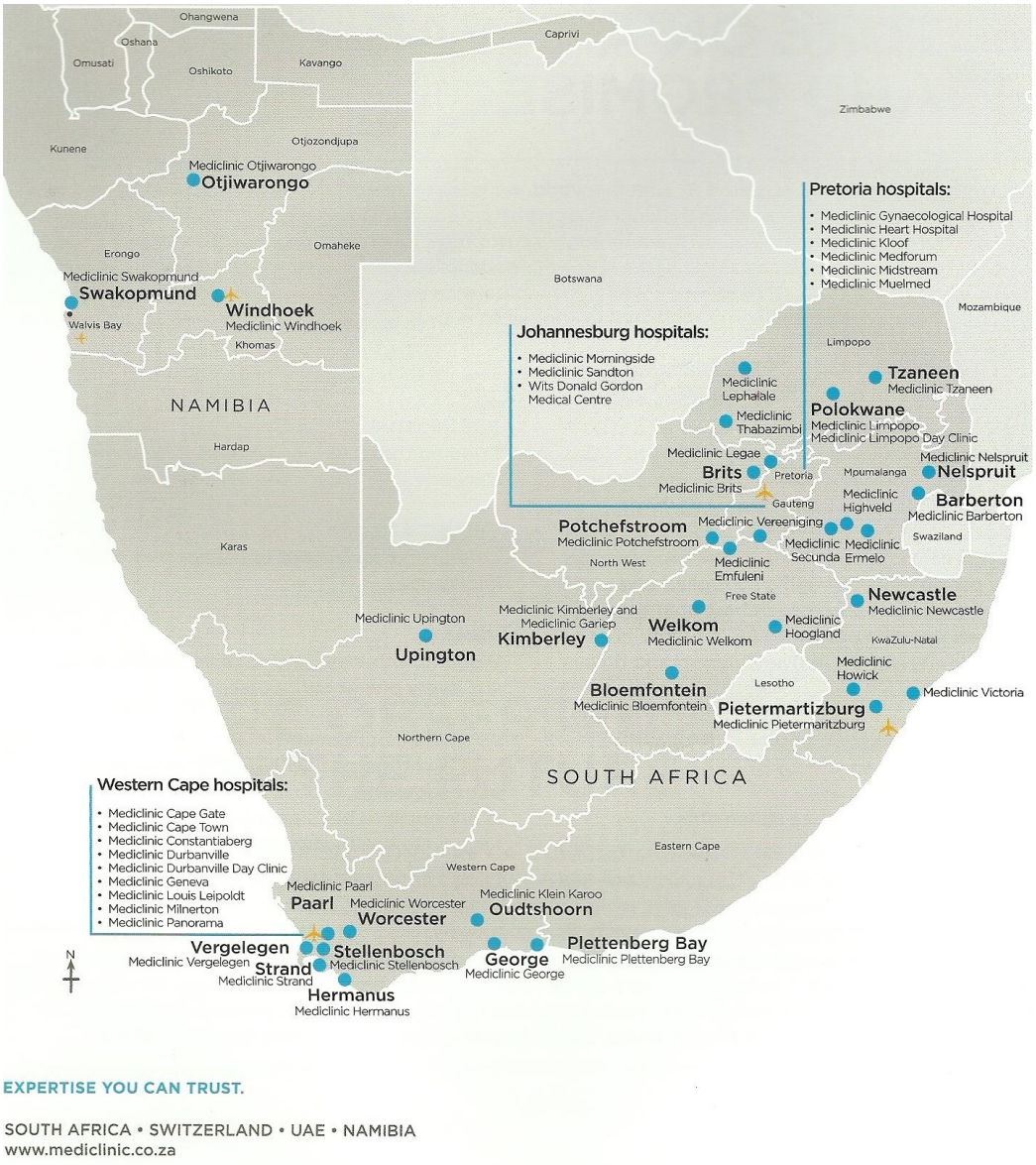


Figure 1.3: Mediclinic Southern Africa Distribution Map

Adapted from (Mediclinic, 2016)

1.3 Problem Statement

This research is aimed at achieving an effective and efficient PAMP, which is to be utilised specifically within operating theatres in the Mediclinic private healthcare group and also to address strategic asset performance within the operational capacity of MCSA hospitals. It is within this regard that research is conducted to investigate the prevention of critical system failures, where the aim is to overcome asset unavailability in regard to addressing competitive pressures of providing healthcare facilities and equipment to practitioners who can be considered customers in choosing to utilise MCSA services. The following problem statement can be considered:

> **There is no guideline or policy framework available for implementing integrated smart asset communication within the private healthcare industry for realising a better management strategy to address the prevention of critical system failures within operating theatres**

In order to address this identified problem a new concept, SAM, has been identified to address a lack of asset communication which has been proven to assist within the strategic asset management decision-making as well as PAM performance management. Where the IAM (2014) describes "the key to making good Asset Management decisions is acquiring appropriate knowledge and applying this within a robust decision-making framework." (IAM, 2014). Asset knowledge is derived from asset knowledge enablers, i.e. asset information. Therefore this research study is conducted to develop a guideline for the implementation of an integrated approach to incorporating asset information within strategic asset management. By developing a deeper understanding of SAM and further exploring the relationship between asset communication and its integration within an AM system, namely PAM, corporate management can monitor asset performance of operating theatres. This in turn is aimed at addressing customer satisfaction to pre-emptively mitigate competitive risks.

1.4 Research Question

Based on the background and the establishment of the problem statement, the primary question for this research is:

> **Can the existing concepts of PAM be improved by the incorporation of reliable and accurate real-time asset data, through SAM constructs set out in a policy framework, to assist in yielding asset knowledge enablers which contribute to reducing critical system failures and improving PAMSE?**

In support of the primary research question, the following sub-questions need to be investigated:

a. What is the foundation of SAM?
b. How can these SAM foundations be incorporated into a policy framework?
c. On what basis can a policy framework be constructed?
d. How can the constructed policy framework of SAM be consolidated and implemented within the strategic management of physical assets within a corporate asset management structure?

These research questions represent informal considerations of the concept of SAM and set the requirement of addressing the formal research question and objectives. Furthermore these questions form the foundation of the need to further investigate the constructs of SAM theory. Existing and proposed research will need to be used to investigate and further deliberate the application of SAM within a specified industry. Another aim is also to expand on the strategic advantages of incorporating SAM in Operational Management to utilise data collected from smart assets to determine quantifiable specifications.

1.5 Research Objectives

From the preceding research questions, the background of this research is indicative that asset managers are at the helm of a technological forefront where tactical decisions concerning physical assets need to be addressed to utilise this technological potential. The objectives of this thesis therefore aim toward delineating the domain and constructs of SAM, to provide an operational definition and to introduce a comprehensive framework for directing future research. The thesis draws on SAM literature in implementation, management and engineering constructs to provide a review of the usage and terminology of SAM.

Therefore, considering the aim of establishing the main research objective of this thesis which is used to address the research question, as given in the preceding section, the research objective is formulated to guide the research aim within an academic process. The primary objective of the study is therefore:

> **Develop a policy framework to assist technical management of private healthcare hospital facilities, with specific reference to operating theatres, to reduce critical asset system failures by utilising SAM concepts.**

This main research objective is dealt with by methodically resolving the research objectives which are highlighted within the following tabled summary.

The first three research objectives as highlighted within Table 1.2, illustrate the preliminary literature review within Chapter 2. This chapter dictates how SAM is a field of study which is not clearly defined as a stand-alone concept within AM and also that currently no framework exists with regards to what is required to implement SAM within a given industry or even a given organisation. Therefore the first three research objectives aim to firstly establish the basis for SAM within AM and PAM. Secondly the available literature appropriate to SAM is discussed and compared to existing industry implementation. Finally this chapter further delves into associated keywords and concepts aimed at defining the outstanding concepts related to SAM which require further analysis.

In Chapter 3, the research objectives listed in Table 1.2, discuss the need to establish an implementation framework of PAM. The implementation of PAM is also discussed within the context of a hospital environment. Furthermore the gap within research is identified to overcome the shortcomings of PAM which can be resolved by implementing SAM.

In Chapter 4, the research design and execution methods are deliberated within the three objectives listed in Table 1.2. The experimental approach founded within academic procedures will be determined as well as further construction of the research methodology.

In Chapter 5, the field work, implementation as well as validity testing are set forward to accomplish the two goals as described in Table 1.2. Firstly the research experiment is conducted, where the required fieldwork is used in concurrence with the research question. Secondly the results gathered from this experimental procedure need to be validated from the associated fieldwork. This is done by analysing and comparing results to illustrate dependency.

Finally, in Chapter 6, the conclusion and recommendations are established. These conclusions are are drawn from the research conducted in Chapter 5, where the applicability and effectiveness are determined from the developed research methodology and the conducted fieldwork. Finally, conclusions are drawn from the resultant analysis, used to address the research question stated in section 1.4.

Table 1.2: Summary of Research Objectives

Chapter	#	*Research objectives*
		Literature study
2	1.	Establish the fundamentals of AM, PAM, maintenance strategies.
	2.	Review the current use and the available academic literature of SAM and related concepts.
	3.	Identify the contribution of SAM within strategic asset performance.
		PAM and SAM Implementation
3	4.	Describe the proposed phases of PAM implementation.
	5.	Compare and select related approaches pertaining to SAM.
	6.	Identify the gap within the current methodology founded on PAM pertaining to the implementation of the proposed concept of SAM.
		Research Design and Methodology
4	7.	Determine the experimental procedure as well as the required fieldwork to concur with the research question.
	8.	Construct a well-defined research methodology.
		Fieldwork: Data Gathered and Analysis
5	9.	Conduct the research within the specified industry to concur with the research question.
	10.	Consolidate information to create a policy framework which is applicable for technical managers to utilise theoretical findings.
	11	Validate results from the associated fieldwork by analysing and comparing data gathered with external verification results to illustrate dependency.
		Recommendations and Conclusions
6	12.	Draw conclusions from the result analysis.

1.6 Importance of the Research and Research Agenda

The term Smart Asset Management inherently falls within the asset management domain and leads to the question, why is the notion of SAM exceptional and does it need to be addressed independently? The rationale and background behind this study is highlighted in the importance of incorporating technological advancements within operational and service orientated sectors utilising PAM principles within corporate asset management. The research agenda is therefore established within a competitive environment where competitive advantage can be gained by, amongst other factors, improving processes through; reducing costs, investigating opportunities, mitigating risks and improving performance through promoting asset throughput and/or availability. In light of this, various industries have adopted automatically driven processes, which can provide more efficient control of assets and asset information as well as insight into asset deliverables. Literature confirms the tendency towards automating systems for achieving informed results. Wang *et al.* (2014) proposed that "*IoT and cloud computing are conducive to helping conventional assembly modelling systems to evolve into an advanced system, which is capable of dealing with complexity and changes automatically.*" (Wang *et al.*, 2014). James Meehan, past president of General Electric Industrial Automation also proposed that "*integrated automation - the inter-linking of all the automated elements of a plant-robots, computers, machine tools, mechanical handling equipment, warehouses, was the key to long term survival for manufacturing enterprises. Successful automation depends not on how many production functions can be automated, but why the company automates its various manufacturing operations and how it goes about it. Some plants have achieved a quantum leap in performance simply by automating just one production function: others have automated their entire manufacturing operation and gained virtually nothing.*" (Livermore, 2000).

With asset management being a key component in SAM, SAM advances AM further to create an individual concept related to the prerequisites of assets to possess intellectual properties which offer the ability to apply asset management more effectively. Therefore the research question and objectives created for this thesis are created to provide a definition but more so to explore the value of implementing a system which enables organisations to improve PAM policies through establishing technologically driven, automated control advancements on existing and newly acquired assets. The processing of data acquired from these smart assets into workable information, which can be effectively utilised by organisations, also needs to be addressed. PAM implications include deliberating and validating the results procured from a SAM system.

This research is appropriate to members of industry who are responsible for managing assets in order to increase performance, increase reliability and/or availability as well as maximising efficiency of related asset-owning organisations regarding the utilisation of their assets. The importance of the research therefore lies in the fact that leaders within management of asset-owning organisations need to be involved with decision-making regarding critical assets utilised within an organisation. These critical components cannot be set aside to be dealt with by only technical supervision. As identified by the Aberdeen group, AM is vital to organisational success (Aberdeen, 2008), and SAM is a possible key to achieving greater PAM excellence within an asset-owning organisation.

It also is important to note that assets are built to serve a purpose and are bound by defined user limits. Therefore by using technology, existing assets can be upgraded in order to be better controlled and have the ability to produce better results. By focusing on assets which are critical in nature or those assets which limit productivity levels, if these assets are effectively managed, improving asset availability and operational effectiveness are key driving factors to further investigate the business potential of implementing SAM.

1.7 Methodology Overview

A qualitative research paradigm has been identified as a suitable means to address the case study focus area of this research. This research paradigm is seen as necessary due to the focus of this study being related toward exploring the qualitative aspects of enhancing operational and corporate management through incorporating technological communication methods to produce asset knowledge enablers allowing better management decisions to be made. This research sets out to primarily comprehend the context of the problems associated with managing physical assets supporting an operating theatre facility within the the private healthcare sector. The exploratory nature of this study allows for the input of both operational and corporate managers to collaborate and generate possible solutions for current situations. In light of the research paradigm understanding, this study follows a pragmatic world view which is qualitative and inherently non-empirical in nature due to the investigative properties of the case study approach which will be utilised. The use of this approach will therefore be delineated to facilitate the employment of the necessary tools and techniques required to address the problem statement. These tools and techniques include a questionnaire; feedback interpretation and visual representation of an appropriate framework encompassing the study. The case study approach is exploratory in nature as described by Yin (2009) as “an empirical inquiry that investigates a contemporary phenomenon in depth

and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.". These concepts will be explored further within the research methodology section.

The structured communication techniques between participants, in this study are a questionnaire and a face to face validation interview, which are developed so as to collect data as systematically in order to address the research question. A constant comparative method is used as an analytic process to explore various data criteria to be captured. The data collection approach is split into two steps which involve analysis to establish an interactive forecasting method which progresses into the second part relying on a panel of experts to validate the data which was gathered and analysed. Their professional experience regarding maintenance and operational aspects are captured within the interview processes, where the group results are analysed to reach consensus regarding various conclusions. Within these questionnaires the experts offer insight into the critical aspects surrounding the facility of an operating theatre. Regional managers and technical specialists react on the surmised information collected to concur on the value contribution of establishing the SAM technique as a means to better manage these facilities. These "experts" are encouraged to revise opinions of the research to highlight aspects which add the most value. The group will converge towards a benchmark and finally the achievement of this study will result in an implementation framework of the proposed solution.

In summary, the following considerations are used to guide the development process of the research framework:

a. Identification of the emerging theories concerning asset communication and related themes
b. Identification of the emergent understanding of SAM establishing a core theoretical consciousness
c. Identification of the existing literature regarding themes pertaining to SAM, establishing a contextual basis. These research concepts are further interrogated whilst considering intervening conditions which contribute to the influence and emergence of the research consciousness, specifically pertaining to smart asset methodologies
d. Identification of strategies within research which pertain to SAM research awareness that can be utilised
e. Identification of SAM consequences that may arise from the newly found theories in SAM
f. Determining how this new SAM awareness can serve as a guidance for regional management to implement the founded strategies to reduce critical asset failures

g. Identification of the propositions to which the theories hold true as well as where value can be added

This single case study serves as a means to develop a framework for management to assist with the integrated phenomenon of technical intelligence within AM.

1.8 Delimitations and Limitations

According to Leedy and Ormrod (2005), delimitation is necessary to conduct a study where it is important to clarify the constructs of the theory prior to the presentation of the research. By creating boundaries for the research, a clearly defined scope can be set forth in which the presented information remains focused and true to the established requirements, whilst still being able to explore related concepts. Within this thesis, a focus is created for the improvement of PAM through the utilisation of "smart" technologically driven processes to acquire asset information which can be incorporated in strategic organisational decisions within an operational environment. With this in mind it is also important to consider, according to Leedy and Ormrod (2005), the key attributes of the delimitation process selection criteria which include the importance of the identified research, the limitations associated with the study as well as the ethical implications concerned regarding people involved within the study. Whilst previous sections dealt with the theoretical position of this thesis, this section sets out to address these factors related to the various limitations, boundaries and focus areas which are associated to the scope of this study. Where the following aspects are included:

- This study is bound by the constructs of PAM and Asset Maintenance (AMa) and therefore contributing to ongoing research which may be conducted regarding the optimisation of asset performance and asset decision-making strategies.
- This study focuses on the introduction and improvement of PAM and AMa systems within corporate management environments through smart constructs. Extensive levels of analysis considering empirical, quantifiable, generalisable and statistical outcomes are not taken into account. The selected case study approach is used to define and substantiate the research problem by collaborating with various operational experts, who have experience with respect to the confines of the case study. The researcher is not a trained sociologist therefore the researcher chose not to include a conditional matrix[1] when addressing these experts. The expert

[1]"An analytic device to stimulate analysts; thinking about other relationships between macro and micro conditions or consequences both to each other and to process (where macro is broad and micro is narrow in scope with possible impact)" Strauss and Corbin (1998)

participation is deemed viable to the study due to the predetermined job description of appointed responsible persons.

- Considering the qualitative nature of this study and given the time constraints for collecting and interpreting data, an online questionnaire will be created to collect the first iteration of data in the case study approach, where a second iteration of interviews is conducted in a face validation approach to validate findings of the research. Due to the limited time frame, this research is constrained to the qualitative feedback from technical managers and corporate managers within the private healthcare sector within the Mediclinic group. These managers are responsible for managing and maintaining technical asset systems and facilities within the group. This study does not elaborate further outside of the focus group.
- This research is also bound by the regulations which govern the operational factors and patient rights concerning the asset utilised within a healthcare environment. These regulations are further elaborated within the next section.

The above-mentioned delimitations and limitations are considered during the execution of the research process where a descriptive outline is provided within the next section.

1.9 Ethical Implications of the Research

This study has various ethical implications concerning the fact that the environment in which the physical assets are found, the private healthcare sector, has certain regulatory restrictions regarding assets which affect patient healthcare where these assets need to be maintained within specific intervals. Some of these regulatory standards include the R158, SANS 10142 as well as the patient rights charter which influences factors such as patient rights as well as patient information which may not be shared. This research is also conducted within a corporate environment where sensitive information may be used by competitors or could have a negative impact on corporate branding. Therefore this research is bound by these regulations and will be conducted in such a manner as not to transgress these regulations. Nor will any research be conducted or any information supplied which negatively impacts the employers or employees in this investigation which is conducted within Mediclinic Southern Africa. Nor will patients and patient healthcare be compromised within any research conducted or findings revealed. This research will also be conducted in compliance with the University of Stellenbosch's ethical clearance committee. This ethical process involves approval for any research to be conducted on any persons cooperating within this study as part of the research process.

1.10 Chapter Outline

Based on a qualitative research design, this thesis is structured in such a manner as to clearly define the processes required within the research as well as results obtained whilst conducting the research. Therefore in the layout and structure utilised within this thesis, sections preceding this section were used to; identify the problem statement, elaborate on the research objectives, define the research agenda and delimitations of the study and finally to explicate the research design and methodology used to conduct this study. Each chapter hereafter will be used to further reflect the research direction, findings and conclusion. The structural layout is therefore utilised to introduce the reader to the predefining concepts and outcomes to be elaborated within the respective chapter. This layout is depicted visually in the chapter introduction, where Figure 1.2 illustrates the document structure of Chapter 1.

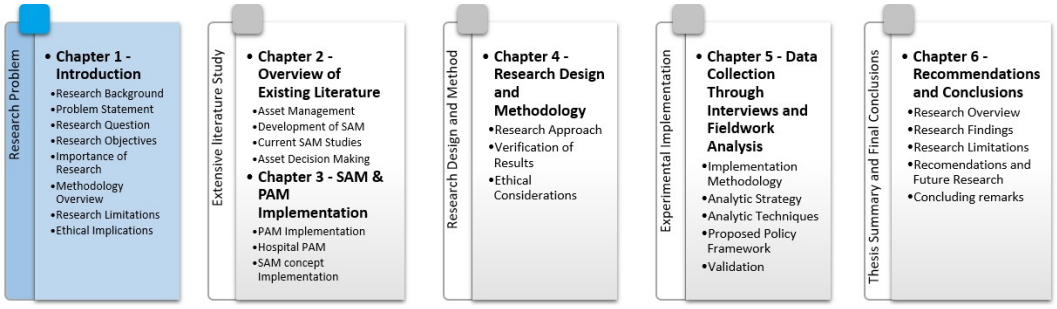


Figure 1.4: Document Structure

Chapter 1 aims to familiarise the reader with the research agenda as well as the structure and implementation procedure which will be conducted. This chapter will also be used to identify the formulation of the research question and the related research objectives.

Chapter 2 aims to introduce existing research pertaining to AM, PAM as well as SAM. In order to do so this chapter first needs to explicate SAM from its origin within AM and then further explore the current academic footprint and practical applications within industry. The numerous variances of SAM which exist are also further explored to illustrate differences as well as common themes within industry. By exploring the origin as well as associated themes of SAM, a SAM literature basis can be established where a contribution can be made towards supporting future research.

Chapter 3 aims to further delineate literature regarding AM and PAM, to provide a clear implementation strategy which can used to create a systematic environment which is conducive to managing physical assets correctly, as defined by various international standards. This section will also focus on the practical implementation for these standards of AM specifically within the healthcare industry.

Chapter 4 aims to provide the framework for conducting the research approach and the academic consideration for creating the implied research methodology. The appropriate procedures for conducting a qualitative case study analysis will be further investigated within literature and applied for the completion of this thesis. The experimental procedure will be further deliberated and the structure for implementation will be established.

Chapter 5 aims to deliberate the experimental procedure which was conducted, providing for any iterations conducted within the questionnaire as well as the responses gathered within the first iteration of the research. These responses will be further analysed to establish trends and consensus concerning the research problem. After establishing the foundation of the research through consensus from the first iteration of interviews, the analysis of the research continues to confirm the nature of the research problem, endeavouring to answer the research question through a secondary interview conducted to elaborate the consensus reached by experts through face validation.

Chapter 6 concludes the research, contributing to the final framework and methodology summarising the feedback of the experimental procedures conducted. Information from these experimental procedures will be analysed, providing feedback regarding the accomplishment as well as the shortcomings which can be improved upon. This section will also be used to direct any future research considerations.

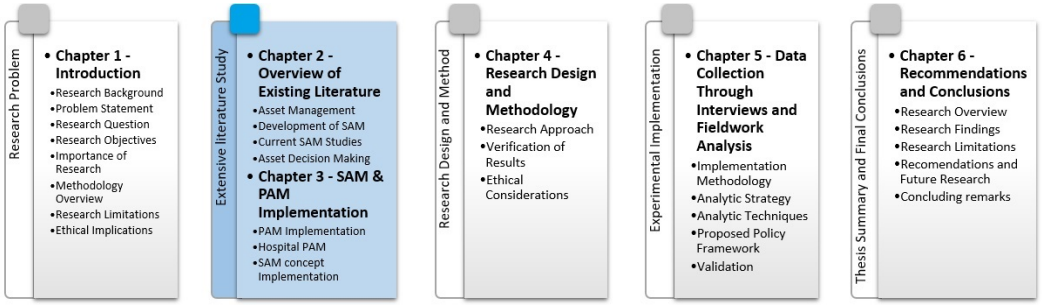
1.11 Chapter Summary

This chapter covers the flow of the research study, where the theoretical background is clarified as well as establishing the research agenda. The problem statement is consolidated within a research question giving rise to various research objectives and the respective sub-questions. The primary focus of this research study is defined within delimitations and limitations of this specific study. The necessity of SAM is established within its potential value contribution as well as the need to establish this new concept within a specialist academic field. The qualitative case study approach is identified as the best option to establish this new concept by consolidating opinions of various opera-

tional experts within the field to reach consensus. These concepts are explored within the succeeding chapters.

Chapter 2

Overview of Existing Literature



Chapter Aims:

This chapter aims to introduce the reader to the existing literature by providing an overview of the research pertaining to SAM. In order to do so this chapter first needs to explicate SAM from its origin within AM and then further explore the current academic footprint and practical applications within industry. The numerous variations of SAM which exist are also further explored to illustrate differences as well as common themes within industry. By exploring the origin as well as associated themes of SAM, a SAM literature basis can be established where a contribution can be made towards supporting future research.

Chapter Outcomes:

- For the reader to become further acquainted with the origin and topic addressed within this study.
- Establishing the interdependence of SAM within AM as well as establishing the independence of SAM as an individual field of study.
- Introduce the current academic knowledge related to SAM which identifies the need to further investigate SAM due to the current lack of academic sources.
- Illustrate the need for addressing AM differently due to technological intelligence acting as a positive driver within a competitive market.

2.1 Chapter Introduction

A literature survey can be described as a detailed investigation as well as analysis of existing theories and keywords related to the proposed concept which is under consideration (Bryman and Bell, 2014). According to Bryman and Bell (2014), existing literature is used as a basis for further research. As will be further discussed within this chapter the proposed concept, SAM discussed in section 1.2, can be associated to various keywords and concept variations as the term SAM itself is not fully explicated in current literature. Due to this lack in research, the identified differences applicable to the common theme will be highlighted within this literature study. These commonalities will be utilised to create a broad understanding of SAM which can be used to facilitate future research that encompasses an ideal implementation of SAM within asset-owning organisations. To define SAM within its own field of study, a suitable definition should represent both a practical implementation as well as an abstract or hypothetical optimum to strive towards.

Concerning the literature framework, as discussed by Bryman and Bell (2014), the facilitation of this literature survey is driven by investigating key words and concepts with respect to a physical asset related "smart" awareness. Therefore starting at the origin of SAM, namely AM, various keywords will be highlighted and discussed individually to pinpoint factors which have been identified to contribute towards SAM. These concepts will be further discussed in section 2.4 which includes the concept of the Internet of Things (IoT). The IoT represents a platform, the internet, where things i.e. physical assets are able to exchange information for various purposes. Other key phrases also related to the intercommunication of assets within their working environment include Industry 4.0, big data, predictive maintenance systems, automated maintenance systems, integrated asset management and the utilisation of Radio Frequency Identification (RFID) tags. These concepts all possess a form of machine intelligence utilised in order to communicate with the surrounding environment to share information and hence assist with strategic AM decisions.

These concepts discussed within section 2.4 relating to smart awareness are further explained in this chapter to introduce the central theme of a technological integration surrounding the information sharing from physical assets. Physical asset management is used a basis to promote the utilisation of SAM considering that the concept proposed by SAM can contribute towards PAM good practices as defined by IAM (2015) within their Asset Management Maturity Scale and Guidance conference paper, stating that "*where higher levels of maturity in Asset Management are often most recognisable in terms of the integration and optimisation of the whole. Furthermore, the "sum of the parts" is also where the Asset Management System sits, ensuring directional alignments,*

coordination, control and continual improvement of all the other subjects". As highlighted within the first chapter, the proposed SAM value contribution lies within this integration of asset information from an operational platform to a managerial platform to enhance the decision-making process. It is therefore within this chapter that existing research will be used a basis to contribute towards SAM as a concept to promote asset management maturity.

2.2 Asset Management: A Brief Discussion

Within this section the integral aspects of AM, which further branch into the concept of Physical Asset Management (PAM) is primarily introduced as the foundation of SAM. A brief overview will be given for the current international standards defining PAM, as well as establishing the defined requirements of PAM and the identified best practices which can be utilised within a variety of industry applications.

2.2.1 Asset Management

AM is becoming a well-established field of research with a variety of definitions, academic sources and alternative variants which further branch out into separate specialist studies. Asset management in the true sense of the term inherently relates to the simple concept of managing an asset. The term asset is defined by Oxford (2016) "A useful or valuable thing or person" hence highlighting an asset an attribute of value contribution. Therefore in essence, the term AM relates to a concept of managing value contribution. However, this simplistic definition creates ambiguity due to the fact that value arises from various sources. The origin of the word asset, as defined by the Oxford dictionary, originates from the old french word "assez" translated as "having enough", where "An asset is literally something of which you have enough. It was originally a term used in connection with paying out money from a will" (Oxford, 2016). Hence the term asset has a monetary connotation, traditionally originating from a financial reference. Within the accounting world, another definition of the word asset is related to "an economic resource" which "can be owned or controlled to produce value and ... is held to have positive economic value ... Simply stated, assets represent value of ownership that can be converted into cash" where "cash itself is also considered an asset" (Sullivan, 2003). This concept is reinforced by Artrill and McLaney (2011), stating that an asset is "a resource held by a business" and an asset should posses the following characteristics for accounting purposes:

- A probable future value
- The organisation must have control over the asset

- The benefit, presented by an asset, must arise from a past transaction or event
- The asset must be able to be measured in monetary terms

Artrill and McLaney (2011) also articulate these characteristics with respect to the future value contribution of physical or tangible assets for example equipment, property and inventories compared to non-physical or intangible assets for example software, licenses and trademarks. Furthermore for financial book-keeping purposes, assets are classified into two distinct categories namely; current assets and non-current (fixed) assets. These classifications refer to the liquidity of the asset with respect to cash. Current assets are held for short periods of time (less than a year) to be traded for capital, whereas fixed assets are kept for long periods of time (more than a year) (Artrill and McLaney, 2011). The potential value of the asset thus lies within the ability for it to be converted into cash, such as a raw materials which need to be converted into a final product, or stock which needs to be sold to generate income. Therefore within these financial terms, an asset refers to the accounting transactions of monetary value, where a record of each significant item is kept within a balance sheet, more so within an asset register to indicate financial well-standing. The opposite financial term to an asset is a liability, where the net worth of an organisation is measured when the total liabilities are subtracted from total asset value (Artrill and McLaney, 2011). It is clearly evident that AM with respect to financial asset management is an important field which requires a concentrated specialist research methodology.

The financial value of assets is also governed by tax laws which stipulate a depreciation value for each specific type of asset (Hastings, 2009). Organisations therefore keep records of existing and newly purchased assets in order to depreciate the monetary value of assets which can be utilised and eventually written off for tax claim benefits within the respective financial year (Hastings, 2009). In light of this, many organisations also consider the initial value of the asset to determine whether it is worthwhile to keep a record and classify an object as an asset. As a result of this behaviour the classification of the asset, in a financial sense, can be governed by the monetary value it has. Therefore a low financial value object may not even be considered an asset. Artrill and McLaney (2011) refer to the physical and economic life of an asset where the physical life of an asset "will be exhausted by the effects of wear and tear and/or passage over time" whereas the economic life "will determine the expected useful life for the purpose of calculating depreciation". However in many instances, although the financial value of an item may be zero, its value contribution within an organisation is still important. For example hospital equipment where although the monetary value has depreciated to nil or the object is no longer considered an asset, the physical equipment

still provides value by supporting the life of a patient. The condition of the equipment needs to be monitored and maintained to ensure this ongoing value contribution. Therefore the value contribution which the asset offers refers to the preservation within a physical tangible nature. This value contribution leads to a separate field of study referred to as, Physical Asset Management (PAM) which will be discussed within the following section.

2.2.2 Physical Asset Management

It is evident that the term asset is therefore dependent on a perceived value creation and contribution. Hence the term asset can therefore also be defined with respect to the value contribution from physical equipment, where AM in this regard relates to the management of these physical items to control or even propagate their value contribution (Schneider *et al.*, 2006; Campbell *et al.*, 2011; Hastings, 2009). Simply interpreted, reference to an asset in this regard suggests the asset requiring ongoing support to ensure effective value contribution. This interpretation of PAM leads to the idea of AM being maintenance related. Assets are recorded within a register, for amongst other requirements, to keep track of when these items require investigation due to manufacturer specifications for example. This concept of a physical asset could be clarified by the term Maintenance Significant Item (MSI) where these assets need to be kept in working condition and furthermore managed in order to perform at optimal conditions set out by the respective asset-owning organisation. Hastings (2009) also highlights the support required by an asset and further expresses the importance of AM as a management discipline to select appropriate assets to perform in the required asset network. Hastings (2009) defines the following characteristics with respect to PAM:

- identifying what assets are needed
- identifying funding requirements
- acquiring assets
- providing logistic and maintenance support systems for assets
- disposing of or renewing assets

Schneider *et al.* (2006) also enforces this concept of PAM as the process encompassing the inception and the dissolution of an asset i.e. an asset life cycle. Schneider *et al.* (2006) further define the management of a physical asset with the following definition:

> *Asset management means operating a group of assets over the whole technical life-cycle guaranteeing a suitable return and ensuring defined service and security standards* - *Schneider* et al. *(2006)*

It is in this respect that PAM not only considers the management of a single asset but rather the management of the environment in which a network of assets operates, encompassing the life cycle of each asset "At the heart of, ... , managing assets lies the ability, both at the individual asset level and the whole portfolio, to find optimal mix" (Woodhouse, 2006). Campbell *et al.* (2011) enforce this notion within their ideals of asset management excellence stating that "asset management excellence is the balance of performance, risk, and cost to achieve an optimal solution". They highlight leadership as the basis of maintenance excellence. Therefore PAM is considered as a management-based field of study which incorporates human operational structures for managing people who manage physical assets (IAM, 2012). Woodhouse (2006) highlights the human assets as one of the most important contributions to PAM:

> *The real, self-sustaining success of integrated, optimized Asset Management is achieved when the top-down managerial direction, priorities and performance goals are clearly aligned with the bottom-up delivery capabilities, opportunity-searching and optimization methods. This is also where the 'enablers' of human factors become so important (every company that has really established a sustainable, continuous improvement habit says that this is the critical bit). The tools and techniques, reorganisations and performance measures all help to make things possible, but ultimately it is people that make them happen. So, in conclusion, the hearts, minds and collaborations are where good joined-up, optimised and sustainable Asset Management lies - (Woodhouse, 2006)*

As discussed thus far, it is evident that various views of an asset dictate the definition of AM, for example PAM and financial AM which look at the same equipment from two contrasting viewpoints. Although both perspectives have various merits; with reference to this thesis the term asset will predominately refer to a physical item, where the term Physical Asset Management (PAM) will be used to avoid any confusion. The term PAM will also be further examined to elaborate on intended strategic benefits within organisations where industry standard definitions will be provided to establish a basis of the research conducted within this thesis. To define PAM, two international standards, PAS 55 and ISO 55000 will be used to clarify the standardised definition of PAM. These sources will also be further explained to clarify their origin and credibility.

2.2.2.1 Preceding PAM Standards: PAS 55

The British Standards Institute (BSI) and the Institute of Asset Management (IAM), were the major contributing organisations with respect to one of the

most recognised international standards specifically related to managing physical objects (van den Honert *et al.*, 2013). The IAM and BSI contributions culminated in the Publically Available Specification (PAS) 55 in 2004 with a later revision in 2008 (PAS55, 2008). The PAS55 standard is a prior publication to the ISO 55000 series, which was also created to contribute towards AM implementation with respect to managing physical assets. Therefore both publications focus on the interpretation of AM with a specific orientation towards PAM (ISO55000, 2014). The key discrepancies between these standards however are the respective objectives of the documents (van den Honert *et al.*, 2013). PAS 55 seeks to elaborate good practices required to manage physical assets PAS55 (2008) whereas ISO 55000 seeks to supply conditional standards used to implement and regulate institutions with respect to an asset management system applied within any organisation (ISO55000, 2012).

PAS55 defines an asset with reference to a physical object; where this object has a distinct value to the organisation and includes the following PAS55 (2008):

1. plant
2. machinery
3. property
4. buildings
5. vehicles

This standard goes on to highlight that physical equipment is merely one of five broad categories of asset types that have to be managed in order to achieve an organisational strategic AM plan. The other categories include human assets, information assets, financial assets and intangible assets (reputation, morale, intellectual property, goodwill, etc.) (PAS55, 2008). AM within this context of an organisational strategic plan, is defined by the following implementation plan:

> AM is the "systematic and co-ordinated activities and practices through which an organization optimally manages its assets, and their associated performance, risks and expenditures over their life cycle for the purpose of achieving its organizational strategic plan" - PAS55 (2008)

This standard also defines an organisational strategic plan as the:

> "overall long-term plan for the organisation that is derived from, and embodies, its vision, mission, values, business policies, stakeholder requirements, objectives and management of its risks" - PAS55 (2008)

2.2.2.2 PAM Standards: ISO 55000

The International Organisation for Standardisation (ISO) is a non governmental institution responsible for international standard-setting where numerous bodies are composed of representatives from various national standards organisations (ISO, 2016). This body is renowned for publishing a variety of internationally accepted standards such as those associated with; manufacturing, health and safety and environmental management. In 2014 a new standard was created, the ISO 55000 series for AM implementation where the standard is focused on "managing physical assets in particular" (ISO55000, 2014). The ISO 55000 series consists of three standards; ISO 5000, ISO 5001 and ISO 5002 where these standards are intended for the use of those who establish, implement, maintain, and improve asset management systems (van den Honert *et al.*, 2013). They further go on to highlight the difference between the three standards in the series:

ISO 55000: is regarded as an overview of what an AM system consists of as well as the terminology used in conjunction throughout the series. The basic principles of AM are discussed as well as the benefits that an AM system offers to various management categories of an organisation

ISO 55001: specifies the minimum requirements to establish, implement, maintain, and improve an AM system. This provides organisations with a set benchmark to asses AM conformity, which allows role players, internal and external, to set a regulatory set point with contractual AM requirements comparing ISO AM standards to the organisation's own AM requirements.

ISO 55002: is a guideline on the application of an AM system as dictated by ISO 55001. ISO 55002 provides support to key role players concerning the implementation and means to uphold an AM system at various management levels of an organisation. This standard also provides insight into the planning, operation, and support activities concerning such an AM system.

There are many similarities between the PAS55 and ISO 5000 series, where both standards focus on the core management of physical objects. According to ISO 55000 these physical objects are defined in terms of assets which "refer to equipment, inventory and properties owned by the organization. Physical assets are the opposite of intangible assets, which are non-physical assets such as leases, brands, digital assets, use rights, licences, intellectual property rights, reputation or agreements." (ISO55000, 2014). An asset as defined by ISO 55000, is an "item, thing or entity that has potential or actual value to an organization", where the "value can be tangible or intangible, financial

or non-financial, and includes consideration of risks". Furthermore the management of these physical assets is defined as the "coordinated activity of an organization to realize value from assets", "Realization of value will normally involve a balancing of costs, risks, opportunities and performance benefits." (ISO55000, 2014). A Strategic Asset Management Plan (SAMP), as used with ISO 55000 is defined as the "documented information that specifies how organizational objectives are to be converted into asset management objectives, the approach for developing asset management plans, and the role of the asset management system in supporting achievement of the asset management objectives" (ISO55000, 2014).

As a preceding document to the ISO 55000 series, the core values highlighted within PAS55 are well established within the ISO 55000 series where both documents are useful as a basis for AM implementation (van den Honert *et al.*, 2013). It is also pertinent to note that neither document replaces the other in terms of value contribution to PAM. However van den Honert *et al.* (2013) go on to conclude that the ISO 5500X suite of standards is a fully encompassing document which reduces ambiguity with respect to PAM implementation and provides the required minimum criteria for AM standards, making it a more user-friendly document. Furthermore due to the fact that ISO is a contributor to various other standards, the ISO 55000 suite is fully aligned to other management specifications such as ISO 9001 and ISO 14001, proving various benefits to organisations which have already implemented such standards. These management principles also overlap between ISO 55000 compared to ISO 9001 and ISO 14001, where examples include quality management concerning assets as well as asset life cycles with respect to disposal of assets and it effect on the environment. These standards can therefore provide various benefits to organisations incorporating these international best practises.

2.2.3 PAM and Asset Maintenance Strategies

With the delineation of PAM from two reputable and internationally renowned standards, PAS55 subsequently replaced by ISO 5500, the definition of PAM can therefore simply be regarded as a means to govern the value contribution of physical items where this governance is inherently performance-related (PAS55, 2008). This governance can also be misconstrued with asset maintenance. Although the discipline of individual asset maintenance is associated with AM, some organisations may misinterpret these two terms, where in fact "Asset management is therefore holistic – it considers the whole picture rather than just the individual contributions" (GFMAM, 2014). According to the discussed PAM standards, the aim of PAM is not limited to only to the maintenance of an individual asset but rather the focus of PAM lies within the empowerment of asset managers to withdraw maximum value via asset systems, encompassing the asset life cycle within an organisational structure

(PAS55, 2008). Due to this comprehensible definition of PAM, a clear divide can be created between the management of an asset and the maintenance of an asset. However, asset maintenance must be considered within AM, as a basic building block contributing towards asset performance and PAM (PAS55, 2008).

Looking at the fundamental term *maintenance*, a definition has been derived from the European Committee for Standardisation as follows, maintenance is the "combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" (prEN13306, 2015). According to the Global Forum on Maintenance and Asset Management (GFMAM) the relationship between maintenance and asset management is very closely related, where "In terms of the 39 asset management subjects as outlined in The Asset Management Landscape, it is suggested that maintenance has influence or major impact in at least 26 of the 39 subjects" (GFMAM, 2014). Mobley (2008) goes on to further define maintenance in a formal Asset Maintenance Plan (AMaP) which "provide[s] governance of all aspects of the maintenance function required to sustain the asset over its life cycle". Higgins *et al.* (2008) also describe this governance of an asset as being related to the theme of Maintenance, Repair and Operations (MRO) where "Every manufacturing facility wants production systems and equipment to operate and be operated in a reliable fashion. When the equipment does what it needs to do when it needs to do it, plant output and profitability is maximized." Furthermore Higgins *et al.* (2008) go on to describe maintenance as not merely being "preventive maintenance, although this aspect is an important ingredient."..."Nor is maintenance simply a frenetic rush to repair a broken machine part or a building segment, although this is more often than not the dominant maintenance activity". This notion of MRO is a business practice related to an organised plan, incorporated within an organisational structure which aims to keep assets functional (prEN13306, 2015). The asset itself is required to be attended to, for example a scheduled service which is predominantly usage or time based, in order to be kept in an 'as new' working condition (prEN13306, 2015).

With these maintenance structures in mind further organisational strategies can be established, where the main requirement of the maintenance strategy is dependent on the need of the organisation. This need is based on the fundamental vision and mission of the organisation structure (Fredriksson and Larsson, 2012). PAS55 (2008) goes on to further simplify this organisational need as often coming down to a basic balancing act between risk, cost and performance. These factors influence the type of maintenance strategy utilised according to the least desired impact or the most required outcome. With respect to a physical asset maintenance plan, various strategies can be incor-

porated to conclude when upkeep should take place. This decision is dependent on the type of maintenance strategy which is applied. The European Committee for Standardisation lists various maintenance types which branch out from two main conditional parameters which are either reactive or proactive to an asset failure.

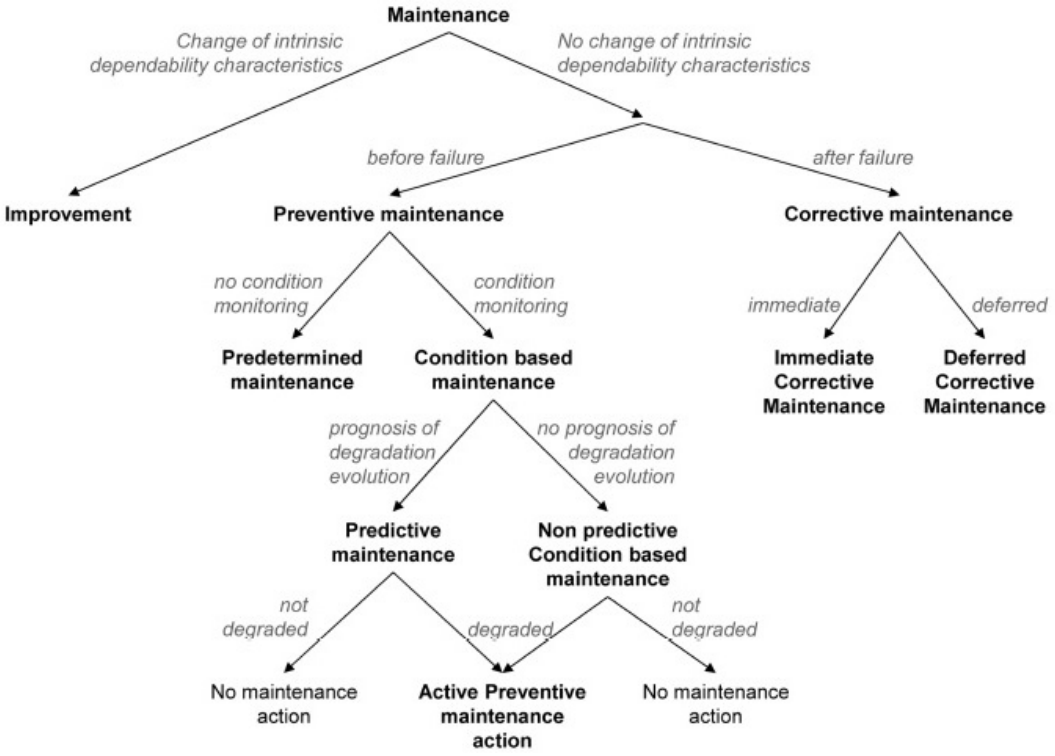


Figure 2.1: Maintenance Types as Defined by European Committee for Standardisation - prEN 13306

Within this breakdown structure, various objectives can be identified within maintenance strategies which assist in deciding which is the most appropriate course of action. Fredriksson and Larsson (2012) confirm this basic concept of reactive and proactive maintenance as corrective and preventative maintenance respectively, where the term predictive maintenance inherently falls within the proactive category and identifies the opportunity of conditional maintenance. Fredriksson and Larsson (2012) also describe multiple maintenance types where the following maintenance types are further elaborated:

- corrective maintenance - where maintenance is carried out after a fault recognition. It is intended to put the asset into a state which is capable of performing its original required function

- preventative maintenance - this is carried out at predetermined intervals, based on time and units of measure which are defined according to prescribed historic criteria. This is intended to reduce the probability of failure or the degradation of the functioning of an item.
- predictive maintenance - asset condition based maintenance which is carried out following a forecast derived from a repeated analysis (a.k.a. condition monitoring). This analysis is drawn from asset information regarding known characteristics and involves evaluation of significant parameters related to the degradation of the item.

According to Salonen (2011), there is also a substantial cost associated with maintenance, where "about a third of these costs are wasted due to poor planning, overtime costs, inferior use of preventive maintenance and so forth". Salonen goes on to further emphasise that if maintenance is "strategically managed, the maintenance of manufacturing equipment contributes to the competitiveness of a company". It is therefore critical that the correct maintenance strategy is identified for the correct organisation. Fredriksson and Larsson (2012) within their research regarding an analysis of maintenance strategies state that "A strategy (direction) is always followed, either consciously or unconsciously. When a strategy is not stated, only followed unconsciously, the result is often a reactive approach, which causes events and others to choose the direction. If a company does not work proactively to avoid failures or the consequences of failures, then the maintenance is operating on a run-to-failure strategy". Fredriksson and Larsson (2012) also go on to highlight the following key maintenance concepts and theories related to implementation and improvement maintenance strategy:

- Total Productive Maintenance (TPM)
- Lean Maintenance
- Reliability Centred Maintenance (RCM)
- World Class Maintenance (WCM)
- Economic Maintenance Development - Life cycle costing, profit analysis and Return On Investment (ROI)
- Asset Data Management - Computerised Management Maintenance Systems (CMMS)
- Key Performance Indicators (KPIs)
- Overall equipment effectiveness (OEE)

- Maintenance improvement approaches - Plan Do Check Act (PDCA), Failure Mode Analysis (FMEA), Fault Tree Analysis (FTA), Root Cause Analysis (RCA), Five Whys and the Fish bone Diagram

The Aberdeen group, within various research agendas, have illustrated that organisations who utilise some of these maintenance strategies, are 80% more likely to reach "best-in-class" performance ratings compared with those who organisations who do not. The inclusion of a successful maintenance strategy incorporated within a PAM framework has been confirmed by various sources, such as Salonen (2011); Aberdeen (2008); Mitchell *et al.* (2007); Campbell *et al.* (2011); Higgins *et al.* (2008); Hastings (2009) as adding value to an organisation. "Optimizing asset utilization is a process of balancing trade-offs between different areas of asset management such as asset scheduling, spare parts replenishment, asset downtime, and the maximizing metrics like Overall Equipment Effectiveness (OEE) and plant throughput. Often this improvement in operational performance can result in the ultimate cost reduction and improved profitability." Aberdeen (2008)

The difference between Physical Asset Management and Asset Maintenance arises from the fact that maintenance is incorporated within PAM GFMAM (2014). As PAS55 highlights, "the organisation shall establish, document and maintain asset management plan(s) to achieve the asset management strategy and deliver the asset management objectives: Creation, acquisition or enhancement of assets; utilisation of assets; maintenance of assets; decommissioning and/or disposal of assets" (PAS55, 2008). Maintenance on the other hand includes "inspection, condition monitoring, functional testing, repair, refurbishment, and/or life extension of assets. Replacement of individual assets may also be considered as maintenance of asset systems" PAS55 (2008). Therefore with this definition in mind, an Asset Maintenance Plan (AMaP) is concerned with the maintenance of the original condition of an asset, where upkeep is required to ensure increased reliability within a Asset Management Plan (AMP). Therefore PAM and inherently a Physical-AMP can be considered as superseding the concept of asset maintenance by requiring the buy-in of management to incorporate PAM into organisational strategy and to implement asset management related strategies within the overall operational as well as the organisational structures. Mitchell *et al.* (2007) conclude that "AM is a pillar of success rather than just good maintenance".

2.2.4 The Link Between PAM and SAM

As discussed in section 2.2.2, regarding the industry best standards of PAM implementation, various sources contribute towards the notion that PAM adds value to an organisation. Considering this value which PAM can contribute,

other sources Salonen (2011); Aberdeen (2008); Berger (2010); de Best and van den Berg (2006); Bouleau *et al.* (2007/2008); Halgamuge *et al.* (2010); Dioguardi and Smith (2010); Glova *et al.* (2014); Liyanage and Langeland (2009); Lopez *et al.* (2011); Schneider *et al.* (2006) have also highlighted the positive contribution of real time asset information being available within an organisation to make better PAM decisions. Aberdeen (2008) goes further to highlight key enablers for successful implementation of Real Time Enterprise Asset Management which includes (but is not limited to):

- Real-time monitoring of asset performance
- Real-time data exchange between systems that reside at the plant floor and ERP
- Workflow automation across plant floor and enterprise applications
- Open architected, interoperable applications.

It is therefore evident that within these established PAM practices which add considerable value to asset-owning organisations, the need is evident for these PAM practices to be established in a real-time environment. Within this PAM value contribution opportunity, the value contribution of SAM is therefore also evident as a means to establish PAM principles in a "smart" technologically aware manner. By doing so, real-time information throughout the organisation is possible, where this availability of information can allow for better management decisions to be made (Nemeth, 2012).

Inherent within any asset management theme is the requirement of asset information and feedback systems IAM (2012). The U.S. Department of Transport defines PAM, within the scope of the transport industry, as being "... a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short and long range planning" (USDepartmentofTransport, 1999). This example of PAM illustrates the relation of PAM to strategic decision making. Asset managers are constantly faced with creating structures to make decisions concerning the assets they manage. Taking strategic decision-making further, the psychologist Leon Mann Mann *et al.* (1988) developed a decision-making framework to classify the basic elements required within a decision-making process. This process is used as the origin for teaching fundamental decision-making theories. Using the acronym, GOFER, Mann highlights the following components required to make a decision Mann *et al.* (1988):

- Goals: review of values and intentions.
- Options: reflection concerning the variety of selections available.
- Facts: the pursuit of information.
- Effects: evaluation of the pros and cons for each decision.
- Review: The implementation strategy and feedback of conclusions.

Just as Mann highlights these requirements for making a decision, so too are these principles applicable to decisions regarding management principles within, but not limited to, PAM concerning strategic business development. Nemeth (2012), describes good and bad decision-making aspects as follows: "Decision making involves choosing among alternatives based on the goals and values of the person or group making the decision. Good or quality decision making involves a thorough analysis of available information and a consideration of alternatives in an unbiased manner." It is further stated that "Defective decisions come from poor information search, selective bias in processing the information, a lack of considering alternatives, a failure to examine the risks of the preferred choice and a rush to judgment". Nemeth (2012) therefore highlights the importance of unbiased, quality information as a requirement for good decision-making. The concept of quality information is clearly resonated within the 39 subjects of asset management IAM (2012) "The quality of Asset Data & Knowledge should be assessed, understood and managed in order to ensure that it provides effective support to business decision making and processes" IAM (2012). AM literature further refers to *asset knowledge enablers* which consist of the following AM subjects IAM (2012)

- Asset Information Strategy
- Asset Knowledge Standards
- Asset Information Systems
- Asset Data and Knowledge

These four asset knowledge enablers illustrate a flow from asset information which leads to organisational knowledge through standards and systems. Oliveira (2007), concludes that "rational decision-making models establish a weighing mechanism between choice and value. Rational methodologies lead to the optimization of the outcomes by emphasizing the process of choosing rather than on what is chosen. A certain alternative is always selected whenever its expected value is greater than that of other potential choices". Therefore rational decision-making is defined by the process of choosing, in other words the structures and standards which govern the choices we make.

Quality information and specifically knowledge, therefore form the basis of quality decisions which may lead to quality results, when applied within a premeditated systematic, standardised operational process.

From these theories it is evident that PAM standards are defined by an individual or a group who have considered which decisions may offer the best outcome, taking into consideration the probability of failure and also acknowledging the potential risks associated with these decisions. This notion of rational decision-making illustrates how PAM leaders need to make rationalised strategic decisions concerning assets. Their decision-making processes should facilitate the growth and development of structures which focus on information becoming knowledge, in order to enable quality decisions which allows for PAM performance improvement. It is within this decision-making process that SAM can play a vital supporting role in accumulating asset information, used to enhance the quality and consistency of these strategic decisions.

2.3 Historical Development and Current State of SAM Implementation

PAM is a well-established field of research with a variety of definitions, academic sources and alternative variants which further branch out into separate specialist studies. However inherent within any asset management theme is the requirement of asset information and feedback systems (The Institute of Asset Managment (2014)). SAM explores this requirement with the use of technological advancements related to communication and processing of information. Due to the fact that there is not a great variety of literature concerning specifics of SAM, the notion of SAM can be deemed relatively new. It has however been identified that the Oil and Gas (O&G) industry could be considered a forerunner of SAM, based on the existing SAM research. This SAM research, conducted by J. Raza and T. Lyanage, from the Centre for Industrial Asset Management (CIAM), University of Stavanger, Norway; elaborates on the theme of monitoring physical assets in real time in order to effectively control the holistic process (Raza and Liyanage, 2007). Terence (2010) emphasised the need for real-time communication infrastructure in the "Realworld Business cases for realtime visibility across oil and gas supply". Commercial product offerings from various organisations also illustrate the footprint which SAM has within the O&G industry: TEGO Inc. using RFID Smart Asset Solutions for oil and Gas (TEGO, 2014), Schneider Electric Smart Oil and Gas Field, Real time data, Real time decisions (Schneider, 2014).

The derivation of SAM from AM is evident as well as the link to PAM, where the value proposition of assets and asset managers has been delineated to es-

tablish the fundamental requirements and best practices of this field of study. To reiterate PAM as a theoretical concept, the Institute of Asset Management declares PAM as "*convert(ing) the fundamental aims of an organisation into the practical implications for choosing, acquiring/or creating, utilising /operating and looking after maintaining appropriate assets to deliver those aims. And it does so while seeking the best total value approach to the optimal combination of costs, risks, performance and sustainability.*"(IAM, 2014). Asset management theory, therefore highlights the combination of strategic targets of an organisation and aligns it controlling deliverables from these assets. Assets are therefore monitored and maintained to operate at certain conditions which deliver results or outputs according to the vision and mission of the organisation. Therefore within the performance management of an asset, or network of assets, asset information can be utilised by the organisation to make quality strategic decisions (Nemeth, 2012). It is within this awareness of asset information that the Smart component of AM plays a vital component.

2.3.1 Definition of Smart Asset Management

The Oxford Dictionary defines smart as "having or showing a quick-witted intelligence" Oxford (2016), where smart when used as an adjective to describe a device, can be defined as "programmed so as to be capable of some independent action". Collins (2003) further describes smart as a *"term for any piece of equipment that works with the help of a microprocessor. Designers are incorporating smart technology into an increasing range of products, such as a smart toaster, which can prevent toast from burning. Smart furniture, such as chairs with cushions that adjust themselves according to the size and weight of a person sitting in them".* As Grogan (2012) highlights within his article, smart appliances are a growing consumer trend where it is evident that the term smart is a marketing-related term which is used to differentiate between ordinary household appliances with those having an ability of above average intelligence. Lopez *et al.* (2011, 2012), Vaishnavi *et al.* (1997) and Gangyan *et al.* (2015) amongst others, have also contributed to the term smart object, where each study describes an object characterised by a degree of technological intelligence which is able to make informed decisions for itself or within a greater network of devices. Furthermore their research details how smart objects are the basic building blocks for various automated systems where each block possesses some of the following attributes:

- In possession of an individual identity
- Sensory abilities to detect information
- Able to store data about itself
- Capable of communication within its own networked environment

- Processing capability to participate in making decisions
- Actuating ability to take various physical actions in response to information

Smart fields, defined by de Best and van den Berg (2006) is described as an integration of technology, processes and resources. de Best goes on to further describe the three key components of a smart field as follows:

1. Reliability of the data
2. Tools to interpret the data and transform it into workable information
3. Skilled operational advisories who can utilise the information for the organisations best interests

According to de Best and van den Berg (2006), asset managers should strive for continuous measurement to allow better decision-making to take place. These researches go on to create an association between the implementation of strategy, and the risk management of assets, where accurate operational feedback allows for managing the opportunity to make more informed strategic decisions.The word smart therefore closely relates to being able to interpret information into workable knowledge which is useful to the end user. This creates the impression of artificial intelligence, where assets can think for themselves and, more so, for us.

As a result of the potential for enhanced asset analysis and the performance possibilities within organisations, the need arises for a clear definition of SAM and a delineation of its implementation within business structures. As this thesis will show, the current use of SAM within industry is not clearly documented, with only a few literature studies and white papers referring to the development and classification of smart assets (IBM, 2011; Luyer; Lampe and Strassner, 2003; Bughin *et al.*, 2010; Liyanage and Langeland, 2009). Table 1 lists organisations which specifically refer to SAM in their value propositions. This list confirms the abundant examples which exist relating to SAM implementation, from retail data mining to financial asset maintenance. Although the concept of SAM is marketed by these organisations, its implementations differ extensively across organisations (IBM, 2011; GeneralElectric, 2011; AssetSmart; tigoenergy; smartassetmanager; Schneider, 2014; Indracompany; TEGO, 2014; Bitplus, 2015; Cognizant, 2015; Eaglecmms, 2015; Elutions, 2015; Gruppohera, 2015; Innovyze, 2015; Minodes, 2015; Olivetti, 2015; Paconsulting, 2015; SAP, 2015; SmartAsset, 2015; Strainstall, 2015; Techsolution, 2015). It is within this variety of interpretations concerning SAM that a commonality needs be identified. Hence, the need for a concise definition for SAM to avoid conflicting terminologies, and establish a basis for future research. It is within these conflicting terminologies that various concepts have already

been established in literature (IBM, 2011; Luyer; Lampe and Strassner, 2003; Bughin *et al.*, 2010; Liyanage and Langeland, 2009). Although these concepts are acknowledged separately, they relate to the central idea of technological process management. These separate ideas also need to be addressed in order to establish a foundation for the further development of SAM.

#	Business	Application	Industry
1.	GE Healthcare Life Sciences	Utility Management	Consulting
2.	Techsolution	Asset tracking	Services
3.	Smartasset	Maintenance	Services
4.	Assetsmart	Asset tracking	Consulting
5.	Smartassetmanager	Vehicle tracking	Supply chain management
6.	Eagle Technology	Asset tracking	Services
7.	Tigo Energy	Energy tracking	Energy & Utilities
8.	Olivetti	Asset tracking	Oil and Gas
9.	Strainstall	Maintenance	Marine
10.	Indra	Energy tracking	Energy & Utilities
11.	Hera	Utility Management	Utilities
12.	Tego Inc.	Asset tracking	Oil and Gas
13.	IBM Maximo	Maintenance	Consulting
14.	Innovyze	Utility Management	Utilities
15.	Schneider	Utility Management	Oil and Gas
16.	Minodes	Asset tracking	Retail data mining
17.	Elutions	Utility Management	Utilities
18.	PA Consulting	Utility Management	Consulting
19.	Bitplus	Maintenance	Financial Services
20.	SAP	Maintenance	Financial Services
21.	Cognizant	Utility Management	Energy & Utilities
22.	Apx-Labs	Utility Management	Maintenance

Table 2.1: Organisations Which Claim to Utilise SAM

It can therefore be said that organisations are within an era of technological performance where electronic goods and technology are overwhelming indus-

try, where market competition is a driving factor for organisations to want to offer the latest technological expertise (Z. Bi, MAY 2014). By investigating the organisations which claim to have implemented SAM, Table 2.1, it is evident that there is a business need within the industry. This necessitates the academic investigation of SAM to establish the prerequisites for theoretical implementation. Assessing these organisations, there is a clear link between the technological requirements of management relating to the electronic convergence of asset communication, through the availability of information which is interconnected within communication structures (Berger, 2011). This link implies the potential for businesses to offer significant information across multiple platforms, making knowledge more accessible to various stakeholders within the organisation. It is within this technical performance wave that organisations will be able to utilise asset information in a number of ways to create market advantage. The Aberdeen group has identified best-in-class industry characteristics which organisations are using in asset management strategies to reduce operational cost, improve profitability and also to improve their competitive edge in the market place. This research speaks to effectively managing resources by reducing manufacturing costs in "technological interoperability" AberdeenGroup (2007), where the increasing emphasis is being placed on the use of technology to monitor the performance of physical assets to operate at optimal conditions, thereby delivering predetermined targets.

2.3.2 Related keywords

Currently available literature regarding SAM does not provide a clear definition or structure for SAM or SAM implementation, yet similar concept variations of SAM do exist. These variations contain a central theme of creating a greater interdependence between technology, primarily concerning information feedback and asset management. This thesis will illustrate how the concept of SAM furthers current ideas to include an aspect of direct asset communication within organisational management structures to better facilitate the control of operational facets. SAM can therefore be considered as taking two concepts and merging them together; asset management and smart equipment (physical assets) which are upgraded to encompass an additional advantage. These assets can communicate within a given structure to assist management and even make predefined decisions, or use artificial intelligence (machine learning) to improve productivity.

The concept of SAM is also said to take the idea of PAM further to imply the use of digital capabilities, as referred to by Liyanage and Langeland (2009), to enhance the control and performance of organisational assets. A *techno-organisational environment* can be created which allows technology to assist the implementation of organisational strategy via the intercommunication between assets with organisational infrastructures (Liyanage and Lange-

land, 2009). *Smart fields* is also used to describe an integration of technology, processes and resources (de Best and van den Berg, 2006). Where the key components of a smart field are reliable data, tools to interpret this data and transform it into workable information and lastly skilled operational advisories who can utilise this information for the organisation's best interests. According to de Best and van den Berg (2006), asset managers should strive for continuous measurement to allow better decision-making to take place regarding the implementation of strategy surrounding risk management of assets. Accurate operational feedback allows management to make more informed strategic decisions.

Due to the fact that the term SAM is still relatively new, various keywords relating to similar concepts have been identified. These keywords are all associated to what this thesis aims to define surrounding SAM, namely physical assets with a predefined *intelligence* which have the ability to communicate within a networked structure. This enables the delivery of information which will allow a system to better manage organisational risk and asset performance. Below are some listed keywords which have been used within research titles or which elaborate key concepts in literature affiliated to SAM:

- Internet of things
- Automated Maintenance
- Smart asset optimisation
- Big data and smart assets
- Smart asset solution
- Realtime asset visibility
- Smart fields
- Integrated asset management
- Integrated trend monitoring
- Integrated operations
- Integrated eOperations
- Business information systems
- Closed-loop optimisation
- Industry 4.0

2.3.3 Development of SAM

Owing to the fact that SAM has rarely been documented within industry implementation, nor has literature defined conditions or created predefined structures pertaining to SAM; it is possible for sources to claim to utilise and

implement variations of SAM for their own purpose. The term *smart* has also become an industry buzz word Grogan (2012), where various organisations claim to incorporate SAM and offer SAM as part of their organisational value add to make use of industry trends, as illustrated in Table 2.1. These organisations all have a shared element in common, offering a means to provide communication, more importantly, asset information feedback from physical assets concerning asset performance, asset location and/or asset well-being. Although these sources cannot be used as objective theoretical literature, where their contribution to literature is considered as white paper with no academic references, these organisations however still reveal a tendency from industry in looking to create a business opportunity from what can be described as an industry common problem: a lack of asset information with respect to making strategic business decisions.

Another concept which has developed related to SAM is that of an augmented or virtual reality. Organisations such as Google and DAQRI refer to 4-dimensional asset monitoring, as illustrated by video clips from DAQRI (2014) and Google's version of Google glass being utilised by apx–labs to improve asset performance (apx labs, 2016). These devices allow the user to view information regarding a physical asset by identifying elements about the asset (bar-codes, RFID tags, physical features, etc.). This allows the user to communicate with a central network server to retrieve useful asset information. These concepts illustrate the need to establish communication with either the asset itself or to communicate with a central body of knowledge to retrieve data or asset information.

In summary, industry requirements surrounding SAM, as referenced by the the organisations listed in Table 2.1, highlight a means of communication being utilised within technological advancements. Some of these organisations go as far as communicating with the asset to identify, locate or collect information from it. Other organisations utilise the technological communication from a central body of knowledge to withdraw information regarding the asset or implement industry best practices to obtain solutions to an asset problem. From the reviewed industry applications it can be conceived that the concept of SAM relates to being able to better communicate with an asset within an organisation. Furthermore the smart ability is related to being able to either unidirectional communication i.e to retrieve information from to the asset or bidirectional where communication goes both ways i.e. to and from an asset. This information can be anything from a unique identifying name to operational conditions of the asset. The smart ability factors in the aptitude of the organisation to interface with the asset to better manage risks and hence make better asset management decisions.

2.4 Current SAM Related Literature

As discussed in section 2.3, the development of SAM is intertwined within PAM and a smart, technological awareness. Although the term SAM is not widely used within literature the concept is discussed in a variety of terminology which is related to SAM. This terminology will be discussed within this section to assist the investigation regarding possible literature sources which are applicable to the further development of SAM as a unique field of study. These associated concepts will be utilised to conduct this investigation further.

2.4.1 Internet of Things Theory and Big Data

The internet of things (IoT) is regarded as the third wave of an technological information industry revolution, where the the computer is considered the first and the internet or mobile communication network the second (Xua *et al.*, 2012). The concept of the IoT, according to Xua *et al.* (2012) was coined by Kevin Ashton of Massachusetts Institute of Technology (MIT) in 1999. This is reinforced by Zhang and Liu (2014) confirming that the term IoT was created and used within MIT Auto-ID Centre and mentioned by Kevin Ashton in 1999 and David L. Brock in 2001. By definition, Zhang and Liu (2014) further describe IoT as an "aim to establish interconnection of objects in the physical world and integrates countless electronic devices around us and a large number of technologies into the network. Hence, co-operate with other people to achieve common goals, interact with each other and provide information in real time [through] standard communication protocols and unique addressing schemes [which] can be achieved by IoT." (Zhang and Liu, 2014). Within their research, Zhang and Liu (2014), explored the utilisation of IoT technology within a fusion nuclear reactor to assist with remote handling systems. Their conclusion related to the fact that by using IoT, an improved operational impact could be achieved by utilising the IoT concerning the maintenance efficiency of fusion reaction devices.

Atzori *et al.* (2010) explored the value add of the IoT by surveying what they considered the most important aspects of the IoT, where the research emphasis lay on approaching this complex concept by evaluating a means to contribute to its development as well as the issues that required further research. Within the research conclusion, it is highlighted that current technologies make the IoT concept feasible but that the scalability and efficiency requirements need to be investigated to determine practical implementation. Atzori *et al.* (2010) went on to further highlight how the IoT has changed the internet drastically, where IoT has introduced a virtual level, within real-world applications which alter contexts spanning from the professional life to social relationships, *"The IoT has the potential to add a new dimension to this process by enabling communications with and among smart objects, thus leading to the*

vision of 'anytime, anywhere, anymedia, anything' communications" (Atzori *et al.*, 2010). Atzori *et al.* (2010) further explored the IoT as a novel paradigm that is rapidly gaining industry awareness where the *"main enabling factor of this promising paradigm is the integration of several technologies and communications solutions. Identification and tracking technologies, wired and wireless sensor and actuator networks, enhanced communication protocols (shared with the Next Generation Internet), and distributed intelligence for smart objects are just the most relevant".*

Another concept related to the IoT is the concept of *big data* and *cloud computing* which are also highlighted within various references to the IoT. These concepts of an interconnected network of machines (assets being able to communicate to a central source) are highlighted within an Internet/Intranet network domain. Wang *et al.* (2014) went on to refer to the IoT as a type of communication platform to exchange asset information via networked devices. Within this research, Wang *et al.* (2014) also described the implementation, the drivers, potential applications, challenges as well as the means which the IoT enables the progression of networked technologies. The ability of the IoT is explored to be able to "help companies to catch emerging opportunities and improve competitive advantage" (Wang *et al.*, 2014). Within this concept of the exchange of large amounts of asset data sets Glova *et al.* (2014) also described the IoT as being a requirement to process the amount of data generated from assets. In order for organisations to manage the amount of data generated from various sources, a central computing power is required to process raw data into sensible information applicable to management structures. This allows data to be processed faster and according to Glova *et al.* (2014) leads to "shorter life cycles of product and services, requiring thus faster changing business models".

Considering the maintenance aspects associated with SAM and the potential for improvement presented by the IoT, Wang and Gao (2012) created a research agenda based on Risk and Condition Based Maintenance (RCBM) presented by the optimisation of maintenance tasks through utilising the IoT technology. By using the IoT, Wang and Gao (2012) described the potential of the IoT in its ability to provide "real-time databases, by using signal-processing, Gray Neural Network, probability statistical analysis and service oriented architecture (SOA) technology, a Risk and Condition Based Indicator Decision-making System (RCBIDS) [can be] built." By integrating a Reliability Centred Maintenance (RCM) program within an IoT platform, various tools or modules can be used in conjunction to improve maintenance of assets. These modules include; a condition monitoring system (CMS), key performance management, server-based file management, fault and defect management, maintenance management; which aims to realise remote condition monitoring, allow-

ing technical maintenance support services ensuring quantitative maintenance decision-making with respect to asset reliability, availability, maintainability and safety. Within their research, Wang and Gao (2012) illustrated that a risk and condition based maintenance task optimisation technology can be used to optimise maintenance content and therefore affect the applicable maintenance period. This allows maintenance deficiencies and maintenance surplus to be minimised and also to prolong the lifespan of equipment. Such a system is illustrated in Figure 2.2.

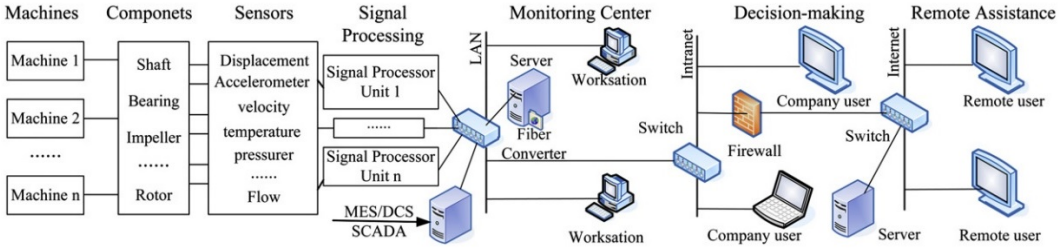


Figure 2.2: Physical Asset Management Illustrated Through the IoT

Therefore the utilisation of the IoT has been illustrated as a key element towards understanding SAM and is implication within asset management as well as the requirement to harness the potential of PAM through technological communication. Furthermore within this concept of the IoT, multiple sources refer to the IoT as a requirement for smart awareness and therefore inherently within SAM Atzori *et al.* (2010); Bughin *et al.* (2010); Wang *et al.* (2014); Glova *et al.* (2014); Zhang and Liu (2014); Wang and Gao (2012).

2.4.2 The use of RFID tags within AM

The term Radio Frequency Identification (RFID) is considered to be related to the IoT as the starting point in a three-stage main evolution series of RFID-based IoT, wireless sensors & actuators, network and smart objects (which cooperate objects) (Xua *et al.*, 2012). Xua *et al.* (2012) furthers depicts this evolution series further as follows:

The term RFID can be utilised as a physical component within a system of devices used for various identification purposes. As elaborated by Atzori *et al.* (2010), the RFID component i.e. the physical device, is referred to as a RFID tag, comprising of a small microchip which is attached to an antenna. This antenna is used for receiving the reader signal and transmitting the unique tag identification ID. This tag is housed within an insulated package which can be attached to an asset in the form of an adhesive sticker (Atzori *et al.*,

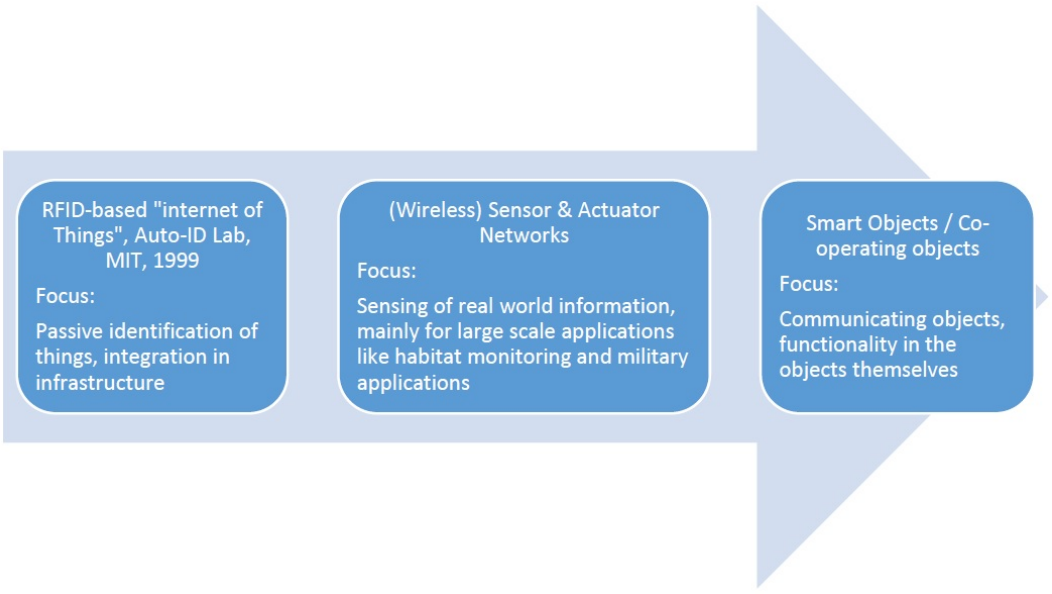


Figure 2.3: The Evolution of the Internet of Things *as adapted by Xua* et al. *(2012)*

2010). Dimensions of this device can also be very small, for example Hitachi has developed a tag with dimensions as small as 0.4 mm x 0.4 mm x 0.15 mm.

With the physical tag in mind, another key component for the implementation of the IoT is an RFID reader, which is used to complete the RFID system infrastructure. This reader is used to detect the unique ID of the RFID tag, therefore an RFID system can comprise of multiple readers and several RFID tags attached to various assets. Atzori *et al.* (2010) elaborates this concept further where "Readers are used to trigger the tag transmission by generating an appropriate signal, which represents a query for the possible presence of tags in the surrounding area and for the reception of their IDs. Accordingly, RFID systems can be used to monitor objects in real time, without the need of being in line-of-sight; this allows for mapping the real world into the virtual world. Therefore, they can be used in an incredibly wide range of application scenarios, spanning from logistics to e-health and security."

The following sources, National Instruments (2014); XERAFY (2010); Dioguardi and Smith (2010); Lampe and Strassner (2003); Xua *et al.* (2012) identify RFID as key element in PAM due to the ability this technology has with respect to *integrate(ting) the digital and the physical world by seamlessly connecting objects in the physical world with their representations in information systems* (Lampe and Strassner, 2003). Dioguardi and Smith (2010) also described RFID as " *the technology (which) provides details of asset location and it can monitor critical information pertaining to each asset; as such, RFID is fast becoming an integral part of everyday life*". As illustrated by Xua *et al.*

(2012), these definitions elaborate that RFID is a basic step to applying SAM methodology, where an RFID tag demonstrates the ability to form a one-way communication system which can be used to identify an asset through radio frequency. RFID however does not establish a communication network within a system, nor does it support the transfer of real-time data regarding the operational information of an asset. RFID definitely has a place within tracking and identifying assets, however a more robust communication network is required in order to fully utilise SAM. In terms of communications protocol TCP / IP is more suited for transferring large amounts of data and this communication protocol is integrated with networked interaction as identified by the IoT.

2.4.3 Integrated Asset Management

The term Integrated Asset Management is referred to by Terence (2010); de Best and van den Berg (2006); Bouleau *et al.* (2007/2008) as the integration of information within asset management, hence a key component towards implementing SAM. Bouleau *et al.* (2007/2008) concluded that "*Those companies that succeed in integrating their assets must have a clear strategy to guide the analysis of processes they need to modify. The ensuing changes can be difficult to implement, much less accept. But the companies that succeed in these efforts will be rewarded with a system in which validated data and customized work flows serve to improve the quality of decision making as they continually optimise their production*". This concept illustrates the importance of an infrastructure which supports the feedback of asset information as a means to steer operations in order to optimize production and system stability. Raza and Liyanage (2011) apply this integration approach within the Oil and Gas sector where their research is conducted within an "artificial neural network", or an interconnected network of feedback from assets to a management system which *demonstrated how neural networks can learn and extract useful information from input data, ultimately transforming it into useful information about the systemś condition...* these conditions "*...can play a vital role in reducing uncertainties associated with the failure events.*" (Raza and Liyanage, 2011). Raza and Liyanage (2011) have contributed extensively towards applying concepts which form a similar theories related to SAM with respect to the management of assets within the O&G industry. These researchers apply their research as a means to better manage assets by utilising smart elements to collect information to process live data within the networked system of assets.

2.4.4 Smart Manufacturing and Industry 4.0

The concept of smart manufacturing has been referred to as a futuristic state of manufacturing by O'Donovan *et al.* (2015) where the real-time interpretation of data retrieved from a factory manufacturing environment creates

intelligence which can provide a positive impact across all aspects of operations. O'Donovan *et al.* (2015) goes on to further reveal the creation of various initiatives and groups which have been formed to advance smart manufacturing. These organisations include the Smart Manufacturing Leadership Coalition (SMLC), Industry 4.0, as well as the Industrial Internet Consortium. O'Donovan *et al.* (2015) describes these institutions as encompassing industry, academic as well as government partners which collectively aim to further the development of strategic policies, guidelines, and road maps which enhance the concept of smart manufacturing and the adoption thereof.

The greatest driving force behind the concept of smart manufacturing, according to O'Donovan *et al.* (2015), is the implementation of data-centric technologies, described by various terminologies namely; Big Data, Machine Learning, Simulation, Internet of Things and Cyber Physical Systems, which are utilised to improve operations within a factory environment. This requirement for improved operations is defined by the ability and importance of improving machine uptime and availability. Therefore the ideal utilisation of smart manufacturing centres on the analysis of data-driven, analytic systems which are used in conjunction with industrial equipment maintenance structures.

The main contributions of this research considering smart manufacturing and big data are implemented within the maintenance environment where data sets and system requirements are investigated to implement equipment maintenance applications within a smart industrial environment. This research focuses on the information system model that provides a scalable and fault tolerant big data pipeline for integrating, processing and analysing industrial equipment data (O'Donovan *et al.*, 2015). The contribution of this research as described by O'Donovan *et al.* (2015) is "considered in the context of highly regulated large-scale manufacturing environments, where legacy (e.g. automation controllers) and emerging instrumentation (e.g. internet-aware smart sensors) must be supported to facilitate initial smart manufacturing efforts."

2.4.5 Summary of SAM-related theories

These variations of SAM which exist have been explored to illustrate the differences regarding the motivation for implementation, however these concepts have also highlighted the common theme of asset information feedback as an important requirement within industry, promoting better decision-making through the integration of asset information. The concepts discussed relate to smart awareness as being a central platform promoting technological awareness to conduct information feedback and information sharing from physical assets. When considering the requirements for AM maturity as defined by

IAM (2015), "where higher levels of maturity in Asset Management are often most recognisable in terms of the integration and optimisation of the whole", this theme of asset integration as highlighted by Raza and Liyanage (2011), with regard to their model of integrated asset management, illustrates how assets which provide a critical role within an organisation's operational production could be better managed by using using SAM concepts to mitigate risks associated with system failure. Their research highlights the possibility of a decrease in tangible failures and in organisational downtime in the form of loss in production, loss in process quality as well as the risks involved regarding personnel safety hazards with respect to system failures. Intangible losses also include organisational reputation, which can cause insurmountable damage due to a decrease in the organisation's public image.

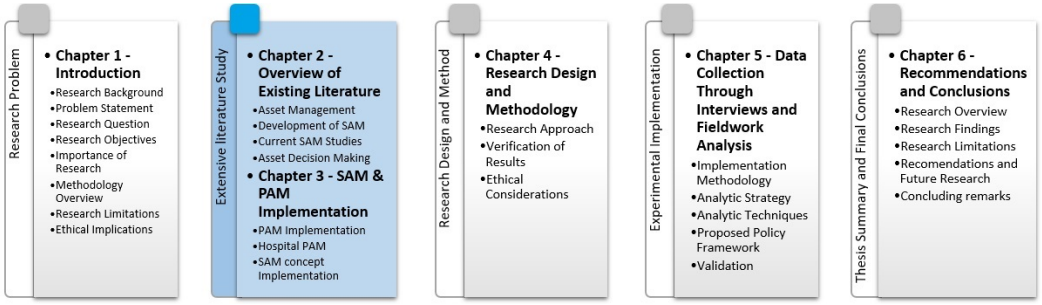
With the concepts as deliberated within this section, clearly highlighting various factors and aspects which contribute toward SAM, it is evident that the concept of SAM is not new. However the phrase SAM is a key component when integrated with PAM to enhance AM maturity. By capturing the information as highlighted within this literature survey, these concepts can be used to implement SAM within the private healthcare sector to prove the value contribution of SAM with respect to implementing better PAM. By exploring the origin as well as associated themes of SAM, a SAM literature basis has been established where a contribution can be made towards supporting future research.

2.5 Chapter Summary

This chapter elaborates on existing research pertaining to AM by establishing the proposed field of investigation within the foundation of PAM leading to the basis of SAM. The origin of AM is further defined by illustrating the framework of which physical assets are defined within a maintenance environment leading to the decision-making frameworks concerning the management overview of these physical assets. Furthermore an investigation was done to explore the current academic footprint and practical applications of SAM within industry, where numerous variances of SAM exist, causing misinterpretations. A variety of organisations are claiming to implement SAM as part of their business model yet their applications differ extensively. With this in-depth investigation of SAM, the literature basis has been established where a further contribution to SAM has been made towards supporting future research.

Chapter 3

PAM and SAM Implementation



Chapter Aims:

The aim of this chapter is to further introduce PAM implementation methodologies as well as those concentrated within the healthcare industry. Furthermore these methodologies will be used to constructively delineate PAM and SAM as well as their related concepts to investigate current PAM context based on the theoretical applications discussed in Chapter 2. This framework for PAM will be used to establish a foundation for this study where objective identification and quantification of PAM will highlight the need for integrating SAM methodologies to improve PAM. Hence supporting variations will be provided to create a primary focus on the intended realisation of SAM.

Chapter Outcomes:

- Address research which contributes to PAM implementation methodologies with specific focus towards the healthcare industry
- Delineate current SAM conceptual implementation methodologies
- Investigate implementation methodologies for PAM and SAM within the private healthcare industry

3.1 Chapter Introduction

The problem statement addressed in Chapter 1 expresses the beneficial factors presented when organisations incorporate elements of automated asset information within Physical Asset Management Strategic Execution (PAMSE). When asset information is collected and interpreted within a smart network of devices, the ability of asset managers to make informed strategic decisions is improved, as further discussed in Chapter 2. Therefore within this chapter, PAM and SAM implementation methodologies are investigated as a means to enhance an organisation's strategic AM execution capability, based on the interpretation of asset information collected. Currently SAM implementation methodologies and the related operational opportunities remain open to interpretation due to a lack of current academic literature. Therefore current methodologies implemented within specifically PAM and also in the healthcare industry will be further investigated to promote the possibility of incorporating SAM.

In order to address some of the present challenges experienced within PAM, this thesis has proposed SAM as a means to improve the primary constraints experienced with regard to sharing of asset information which has been identified as limiting the potential of asset managers to make informed decisions (USDepartmentofTransport, 1999; Baum, 2012). Where the IAM (2015) has confirmed that PAM excellence is achieved when "continual improvement building on experience and the systematic use of asset information" is incorporated within PAMSE, as implemented by management in asset-owning organisations. The literature review in Chapter 2 has also introduced the fundamentals of studies that investigate the application of smart concepts within the PAM environment. Furthermore, Chapter 2 singled out dysfunctional information exchange and poor decision-making as the primary constraints in PAMSE and showed that SAM stands a chance of discerning problems in these domains. By utilising the SAM concepts, the literature highlighted within this study provides evidence for the investigation into the application of SAM in PAM and has laid out the basic knowledge for this ambition. Within this chapter, the aim is to incorporate these concepts deliberated in the previous chapters to investigate various application methodologies, appropriate to the healthcare industry. The aim is to explore the informal networks of information flow and decision-making in PAMSE at hospital management level.

3.2 General PAM Implementation Approach

As highlighted by the Institute of Asset Management, there is no perfect PAM model (IAM, 2014). This is a result of the variety of useful designs and methodologies which are applicable to a basic framework which guides what needs to

be accomplished for a successful PAM system. According to the IAM (2014) the 39 subjects identify and highlight a PAM framework which has been designed to describe the overall scope of Asset Management as well as the high-level groups of activity which are required within the PAM discipline. This model highlights the fact that Asset Management is about the integration of various aspects or groups of activity and not silos of individual capabilities which act in isolation. This model also emphasises the critical notion that PAM needs to be aligned with organisational goals and strategic aims. Therefore this essential alignment of PAM activities through organisational goals is conceptualised within the following figure:

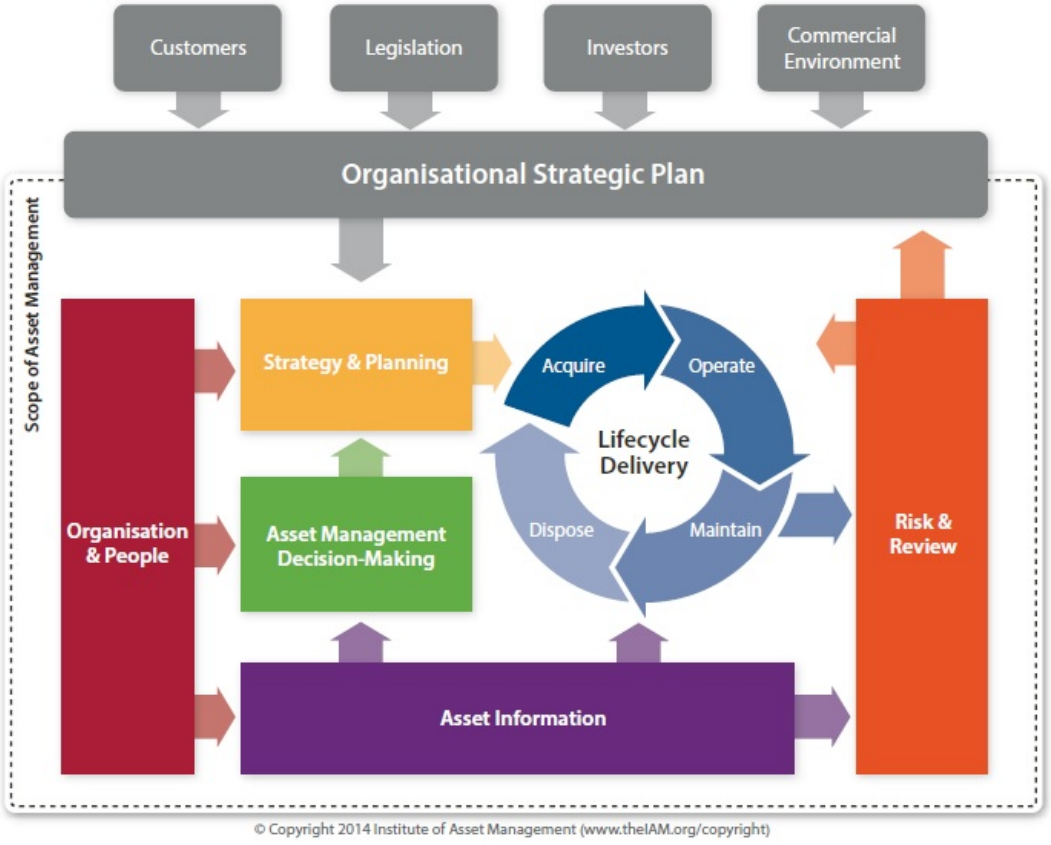


Figure 3.1: The IAM Conceptual Model

Adapted from IAM (2014)

According to the illustrated scope of PAM as depicted within Figure 3.1, the outlying structure concerning the guideline and practices for an ideal PAM methodology are emphasised. It is evident within this model that asset information plays a vital role in PAM. Asset information is illustrated as the basis of the model, a basis which is used to implement and maintain an asset

life cycle; key to providing feedback in analysing risks; as well as the starting point to AM decision-making which further leads to strategy and planning on an organisational PAM level.

Each aspect within Figure 3.1, is further individually deliberated in the PAM model created by the IAM (2014) as means to explicate a framework delineating the important factors pertaining to PAM. This model is essentially founded by on 39 subjects created by the GFMAM (2014), where these criteria form a methodology formulating the core of PAM principles and its theoretical incorporation within various industries. The 39 subjects go into detail describing the processes involved in creating a PAM landscape for introduction, implementation and sustaining a PAM strategy within an organisation. ISO 55000 goes on further to set guidelines and processes concerning the implementation of PAM. The ISO 55000 series defines a management system used for managing physical assets where conditions for establishing and achieving good PAM practices is defined. However according to IAM (2014), ISO 55001 "does not actually prescribe the physical activities, it can best be thought of as a structure to ensure that the organisation achieves what it sets out do in a consistent and efficient manner by means of managing its assets - essentially through controlled processes". Looking at the greater implementation and utilisation of PAM within an organisation, ISO55000 (2014) proposes a PAM model which is used in conjunction with organisational strategy illustrating the boundaries for the organisational environment in which PAM strategy should be developed. These boundaries are illustrated in Figure 3.2.

Figure 3.2: AM Organisational Relationship Model

Adapted from ISO55000 (2014)

According to ISO55000 (2014), it also does not prescribe the extent to which an organisation needs to implement PAM. This decision is dependent on the organisation and context in which the organisation is operating. The 39 subjects listed within the PAM anatomy as described by IAM (2014) list principles of PAM which go beyond the requirements set out by the ISO 55000 series. The original scope of the 39 subjects is aimed at addressing any person who intends to become demonstrably competent or expert in the field of PAM. The implementation of PAM is also originally set out within PAS55 (2008) which highlights fundamentals of PAM, as revised in the six primary pillars or subject groups which interlace the various aspects focused on the implementation and conservation of PAM. These six primary pillars are further distinguished in Figure 3.3.

Although the IAM goes into further detail describing all six subject groups, it is important to note that even though these subjects are described individually, they should not be considered as discrete individual concepts. As depicted by Figure 3.3, between each subject exists an interrelationship where these themes contribute as a whole to an organisation's PAM capabilities as well as the implementation thereof.

To conceptualise or even understand the implementation of PAM, the standards and guidelines set forth by IAM (2014); ISO55000 (2014); GFMAM (2014); PAS55 (2008) can be used as a guide to illustrate the interconnected nature governing the framework which constitutes a cognitive process for planning in advance concerning physical assets. Asset management excellence, according to Campbell *et al.* (2011), is incorporating these "models and frameworks to set a road map and priorities for improvement". The Aberdeen (2008) group also emphasise that the successful implementation of AM relates to the standardisation of asset maintenance and reliability processes where a continuous improvement mentality needs to be established. Furthermore the environment in which AM is implemented needs to be considered as discussed in the next section.

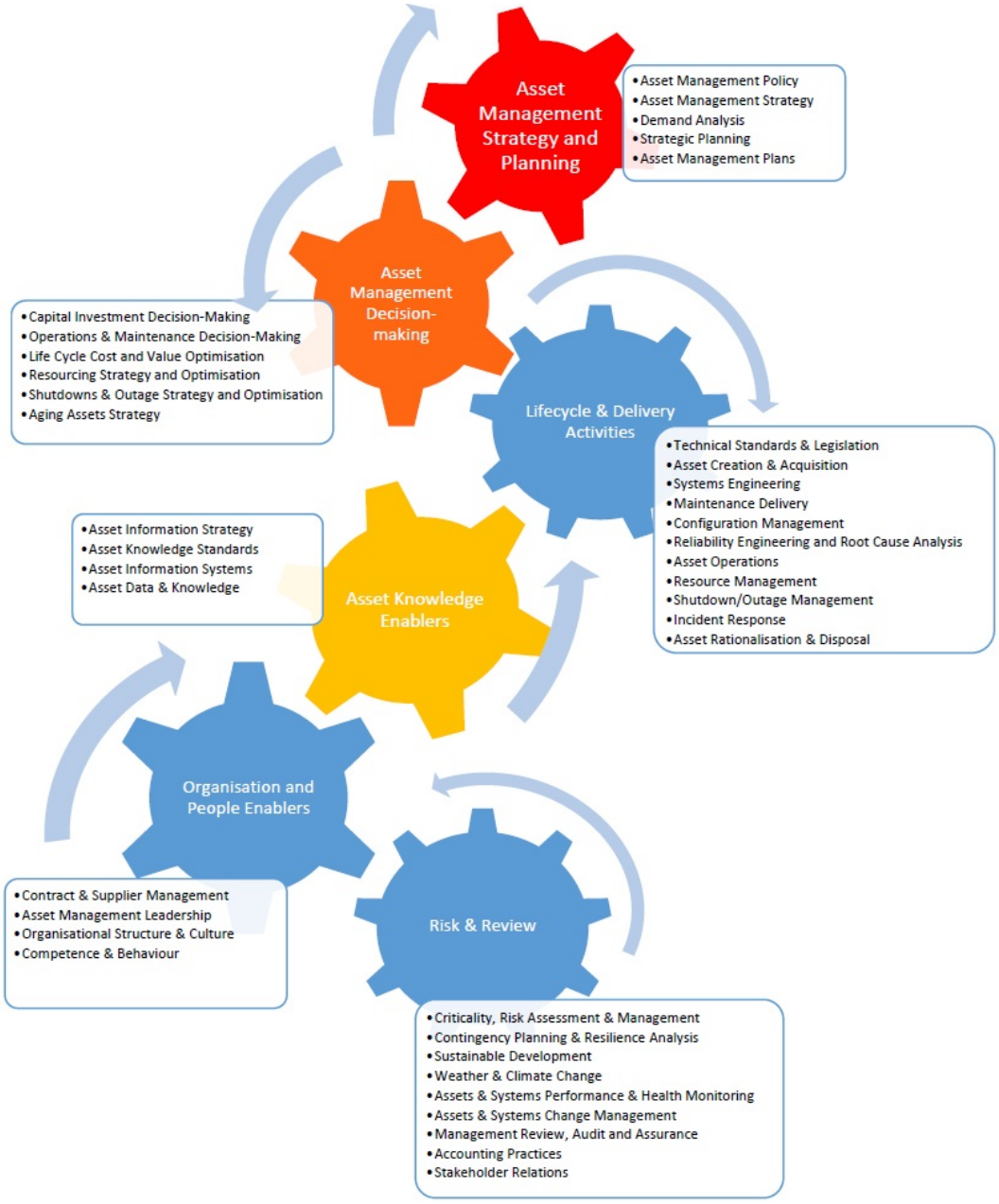


Figure 3.3: Six Primary Pillars to AM

Adapted from PAS55 (2008)

3.3 Hospital Specific PAM

With specific reference to PAM within the hospital environment, this section refers to the management of physical equipment in terms of general maintenance as well asset life cycle management. An effective Physical Asset Management Plan (PAMP) which is related to maintaining medical equipment according to the WHO (2011), consists of adequate planning, management and implementation. It is within these three spheres that the financial, physical and human resources required to adequately implement the maintenance activities should be considered. To identify the correct PAMP the financial, personnel and operational aspects need to be continually examined, managed and improved where necessary WHO (2011). This ultimately leads to proper implementation of the PAM and is key to ensuring optimal equipment functionality.

According to the World Health Organisation WHO (2011), health technologies are an essential basis for the correct functionality of an effective healthcare system. Medical equipment which is considered hospital assets, can directly affect human lives. Hospitals within the private healthcare industry are also considered businesses where apart from dealing with human lives are also accountable to management to be a profitable organisation, where assets are also considerable investments and maintenance costs need to be factored into the return of asset investment as well as income generated from asset utilisation and performance. It is therefore important to have a well-planned and managed maintenance programme that is able to keep the medical equipment in a healthcare institution reliable, safe and available for use when it is needed. Recognising this important role of health technologies, the World Health Assembly adopted a resolution, WHA60.29, in May 2007 (WHO, 2011). The resolution covers issues arising from the inappropriate deployment and use of health technologies, and the need to establish priorities in the selection and management of health technologies, specifically medical equipment. The PAM maintenance resolution, referred to as the Maintenance Program Planning (MPP) prescribed by WHO, is specified within Figure 3.4.

Another institution, Duke University, has also conducted research with regards to a Medical Equipment Management Plan (MEMP) which is defined as "*the mechanisms for interaction and oversight of the medical equipment used in the diagnosis, treatment, and monitoring of patients. The related policies and procedures govern activities from selection and acquisition to incoming inspection and maintenance of medical equipment. The mission is to ensure that equipment used in patient care is safe, available, accurate, and affordable.*" Hughes (2016). Furthermore this institution highlights the need for continual evaluation of the management plan as well as continual performance

Figure 3.4: Maintenance Program Planning

Adapted from WHO (2011)

improvement standards which need to take place. Within the MEMP, various correlations exist to the WHO management plan where continual evaluation and performance management systems are key elements highlighted within the implementation procedure Hughes (2016).

A healthcare organisation, which operates in Australia and New Zealand, NSWHealth (2005), has developed a Strategic Asset Management Plan to establish a PAM programme in healthcare facilities due to the extensive locations in which this organisation operates being widely distributed throughout a number of states. The asset infrastructure is strategically divided between facilities and medical equipment. According to the NSWHealth (2005), the organisation currently spends approximately AU$ 600 million per annum on capital projects, minor works, repairs, maintenance and renewals. Capital spending has been marked at the highest level due to the steadily increasing expenditure which according to the NSWHealth (2005) does not adequately accommodate changes in the nature of construction, advances in technology, the absorption of building cost escalation and increased servicing and maintenance requirements. The NSWHealth (2005) have ascribed these escalating maintenance costs to uncontrolled expenditures which require intervention. As a result of this challenge facing asset management across the health system, the NSWHealth (2005) aimed to reduce expenditure through advancing their PAMP.

Due to the nature of this organisation receiving its funding as a public enterprise, the delivery of public services and supporting infrastructure is unlikely to change. Therefore it is improbable that there will be a dramatic increase in the amount of public funding available. As a result the use of finite resources needs to be optimised to gain maximum advantage and development of ways to improve the efficiency and effectiveness of capital is essential. The NSWHealth (2005) define their PAMP as follows, *"Strategic Asset Management Plan addresses broader Government policies and strategies, and provides a context for decision-making. It articulates a shared and sustainable direction, while allowing for appropriate responsiveness to the dynamic health environment."* (NSWHealth, 2005). Furthermore this organisation strives to include AM as a key focus area within healthcare industry regarding a *"Health Strategic Asset Management Plan explains the major asset strategies and reforms. It addresses details of the NSW Health asset portfolio, strategies for its realignment to meet service gaps, asset maintenance requirements, disposal strategies, monitoring processes and sustainability policies."* (NSWHealth, 2005).

The main focus of this organisation is to link the outcomes of the Asset Strategic Planning Process to provide a mechanism which incorporates health assets with health service needs. Therefore the basis of the PAMP is derived from a services platform and will used to establish the gaps between asset demand and supply. By doing so, a performance measurement can be established which will assist in defining the foundation as well as the needs and benefits of the users which receive the services. In this regard it will enable the organisation to be able to provide a benchmark for establishing an asset programme within specific regions. Local asset programmes, combined with other statewide programmes, will input into the ongoing refinement of the NSW Health Infrastructure Strategy. NSWHealth (2005) has highlighted that this Asset Strategic Planning Process has enabled this organisation to achieve the following:

- Effectively plan for assets and facilities in relation to available resources to assist in meeting current and future health care needs of the community;
- Balance the costs of service delivery with health care responsibilities;
- Provide accurate asset and facility information to enable informed decision-making.

Furthermore the NSWHealth (2005) define four main stages in the Asset Strategic Planning Project which involve the following concepts:

1. Data collection

- Asset demand inputs (from Area Health Care Services Plans/Clinical Services Plans
- Asset supply inputs (from asset surveys/audits; availability; health planning unit assessment in terms of condition, compliance and functionality)

2. Analysis
   - Gap analysis (area shortfall/excess established)
   - Strategic asset review (impact of area mismatch, condition, compliance and functionality)
   - Analysis/Assessment (costing and prioritisation)
   - Assessment of strategic importance (AHS wide review)
3. Area asset strategic plan production
   - Prioritised capital investment with respect to acquisition and disposal plan (asset life cycle)
4. State asset strategic plan production
   - State asset coverage to promote community service delivery

With these factors in mind regarding a regional and national asset management programme, the NSWHealth (2005) has opted to implement their asset strategic planning model, through a web accessible database tool that provides accessibility for the preparation of asset strategic plans regarding both an Area (regional) and Statewide (national) level. Ultimately the intention for this organisation regarding their asset strategic planning, is to be a continuous and dynamic process which is based upon the collection and analysis of standard data which is executed by the application of standard methodologies to achieve consistent reporting outputs. It is clearly evident that this AM strategy is aimed at providing a link between clinical service planning and asset needs within the organisation to assist delivery of services through the PAMP.

Within this context of accessible organisational data which is utilised in a consistent manner, executed through established methodologies, further facilitates the strategic execution of PAM. It is within this concept that the fundamental application of SAM is established to implement PAM processes in a corporate organisation. This concept will be discussed further in the succeeding section.

3.4 Strategic Execution of PAM Inter-linked With SAM

"*The successful execution of a physical asset management strategy is an important value driver for organisations that are highly dependent on the service delivery of physical assets. Research demonstrates that strategic targets are often not met, and that the means to detect the constraints that can undermine strategy execution efforts are deficient*"(Baum, 2012). Baum within his research regarding the primary constraints in the strategic execution of PAM, identifies various factors which contribute to success as well as the opposing difficulties. Furthermore he states that "*A study found that dysfunctional information flow and poor decision-making are the primary constraints that can hinder the PAMSE.*" Baum (2012). Within this realisation it is evident that information which stems from asset data are important factors which contribute to successful PAM implementation.

Considering the 39 subjects of PAM, as previously presented by the IAM (depicted within Figure 3.1 and Figure 3.3), the primary themes pertaining to SAM as presented within this study, create a focus of the opportunity of utilising SAM with asset data in order to make more informed, real-time management decisions. When considering the asset data, the focus needs to be placed on efficiently recorded and interpreted data leading to greater ability to influence PAM decisions which assist with executing PAM strategy of an organisation (IAM, 2014). This concept has been further highlighted in Figure 3.4 where the following subjects of PAM will be further investigated to assist in creating a SAM methodology:

- Asset Knowledge Enablers/Asset Information
- Asset Management Decision-making
- Asset Management Strategy and Planning

Considering PAM as presented by the IAM, Figure 3.4 depicts the interconnections between the various categories leading to successful PAM implementation. Therefore with reference to the three identified subjects, it is evident that these modules also influence other spheres of PAM implementation. For example asset information contributes towards the asset life cycle which assists with asset maintenance as well as influencing the review of asset risk and asset decision-making. The contribution of asset information is also influenced by the organisation and the people who process the asset data into useful information. When considering the application of SAM, to achieve successful PAM, all six subjects need to be considered as a whole. It has however been

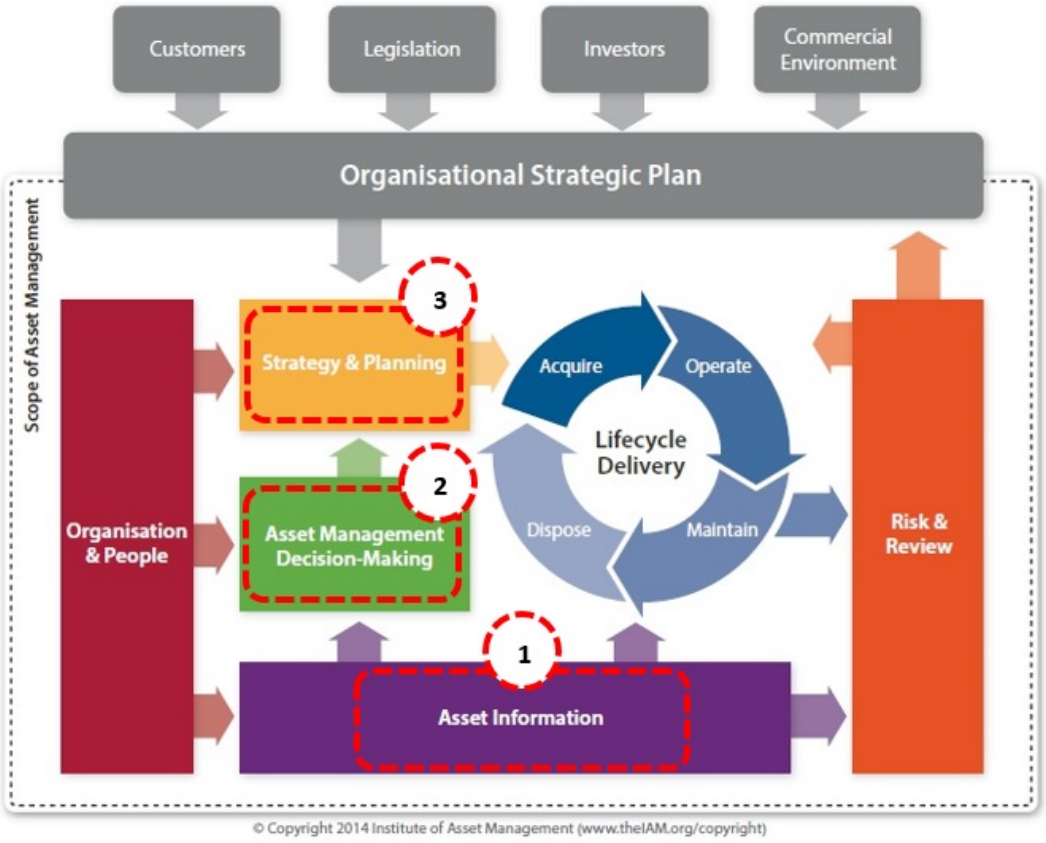


Figure 3.5: PAM Anatomy with SAM Focus

Adapted from IAM (2014)

identified that the three indicated subjects need to be further discussed to investigate possible gaps within the existing framework which can be addressed by implementing a SAM solution.

3.4.1 Asset Knowledge Enablers/Asset Information

The term asset knowledge enabler and asset information has been used interchangeably by the IAM within revisions of the PAM anatomy. The term asset knowledge enabler therefore implies a factor which facilitates the acquisition of asset knowledge, where in this case asset data is the basic building block used for assisting this transition. This concept is further highlighted by the IAM (2014) where asset-owning organisations rely on asset data to be converted into useful information, which when interpreted within a given environment creates knowledge leading to wisdom which enables the opportunity for quality decisions to be made. Wisdom acts as the key enabler in undertaking both strategic AM activities as well as operational activities (IAM, 2014). The four terms; Data, Information, Knowledge and Wisdom are used to segment the

concepts of promoting asset data to strategic wisdom discussed further within this section.

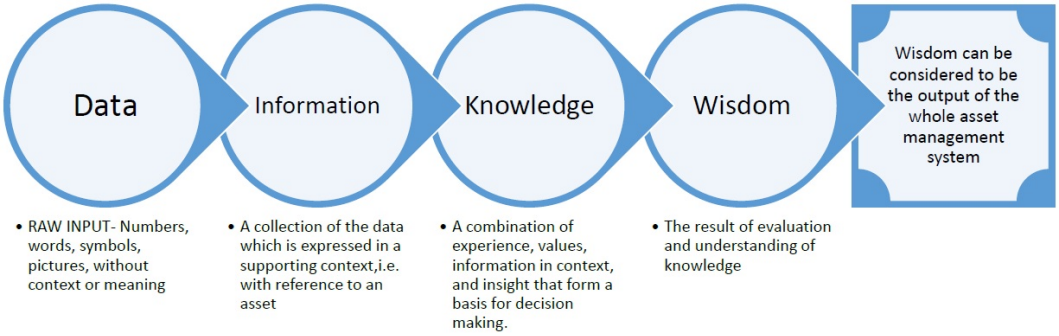


Figure 3.6: PAM Processing of Asset Data to Reaching Wisdom

Adapted from IAM (2014)

As further discussed within the 39 subjects of the asset management anatomy, the IAM (2012) discusses asset information into four separate subdivided sections, namely;

1. Asset Information Strategy (AIS)
2. Asset Knowledge Standards
3. Asset Information Systems
4. Asset Data & Information Management

The term strategy is a basic concept which relates to a plan of action which is created in order to achieve a desired goal. With respect to asset information strategy, this concept relates to the overall plan to achieve the required quality information (IAM, 2014). Snitkin *et al.* (2010) in their research described asset information as "*... a quintessential part of every capital asset investment. Organizations need it to manage the use and care of complex physical assets and it must be complete, comprehensive, accurate and accessible to achieve optimum asset performance. Despite its importance, few organisations have a proper strategy for managing this valuable resource. The cost of this is staggering, both in financial terms (1.5 percent of revenues each year) and increased risk of major incidents.*" (Snitkin *et al.*, 2010). Snitkin *et al.* (2010) support the notion that poor Asset Information Management (AIM) is the root cause for asset performance problems which are related to asset utilisation, poor maintenance efficiency and high maintenance costs. Where poor AIM can also increase the risk of safety, health and environmental incidents due to a lack of quality asset information. As with collecting asset data, a specific management

approach needs to be set out in an overall Asset Information Strategy (AIS). This approach defines the actions that an organisation will need to undertake in order to ensure that the information collected from its assets meets current and future prerequisites. It is within this context of collecting asset data that SAM plays a vital role.

Taking a step back with regard to AIS, the term asset information is defined by the basic requirement to assimilate information, where this asset information is a collective term which can be used to include the following general information types, as defined by (IAM, 2014):

- Evidence of physical asset existence, collectively assembled within a list i.e. asset register.
- Details regarding the assets i.e. make, model, serial number, operating age, rated capacity, etc.
- An evaluation of the asset system detail and its capability
- Spatial information regarding the placement of the physical location of the asset as well as its dependencies
- Operational access control i.e. right of way requests, safety-related information etc.
- A logical grouping with similar asset types
- Asset performance measurements which covers asset availability, reliability, condition and serviceability assessments
- The ability to track historical events and record keeping of work / maintenance completed as the consequence of either unplanned tasks or scheduled maintenance
- Documentation pertaining to the asset e.g. CAD design models and drawings, datasheets, metadata etc.

Asset Information Standards are used to define explicitly the data and information that is required, why the data is required, how it is collected and measured, the format it is required in, who should provide it and when it will be provided. The ISO 8000 series of standards provide useful guidance on the management of asset information.

Asset Information Systems, are the collection of processes, applications and technology, utilised to automate Asset Management processes and to enable consistent decision support analysis. These are often integrated but must always share the same key fields and codes to avoid misinformation to achieve a single version of the truth.

Considering that asset knowledge is set forth in the information systems which contribute to acquiring information, these elements then form the foundation or crucial starting elements toward Asset Management Decision-Making. Asset knowledge needs to be grouped into effective decision-making processes set forth by a asset strategy where the strengths, weaknesses, opportunities and threats need to be extensively deliberated. Furthermore once the information has been gathered the effective transition from information to action is the decision required to effect the change. Asset Management decision-making, with effective asset information is therefore key toward implementing a successful asset management strategy.

3.4.2 Asset Management Decision-making

Asset Management Decision-making can be considered a process evident throughout all stages of the asset life cycle (IAM, 2014). It is a crucial influence which should be adapted within a coordinated fashion to optimise whole life value; where fundamental constraints, statutory legislation or regulatory obligations need to be frequently regarded. Continuing with the Anatomy of Asset Management (IAM, 2014) as a basic foundation for this discussion, guidelines have been set forth regarding the following subcategories with respect to elaborating the AM decision-making process, where focus has been placed on the following concepts:

- Capital investment Decision-making
- Operations and Maintenance Decision-making
- Life Cycle Cost and Value Optimisation
- Resourcing Strategy and Optimisation
- Shutdowns and Outage Strategy Optimisation
- Ageing Assets Strategy

GFMAM (2014) goes on to further define these decision-making procedures as an evaluation approach, where these evaluation approaches include steps of definition, characterisation, assessment and analysis that deliver the best options to assist managers in the decision-making process. Ultimately, these

outlined decision-making processes stem from a strategic plan and need to be adhered to by the people providing information as well as those making the decisions. Therefore when considering the basis of decision-making one has to consider the psychological basis for effective or quality decisions. (Nemeth, 2012), goes on to fully elaborate the requirements as well as consequences of good and bad strategic decision-making by organisations. Nemeth also clearly emphasised the requirement for good quality information or knowledge, as well as the administration thereof, at the basis of the decision-making process.

> "*Strategic management requires analysis, decisions and actions by an organization to create and sustain competitive advantage. Good decisions are obviously desirable but whether the decision is good is a judgement call, often after the fact, and is itself subject to bias. What is less subject to debate is the process that leads to accuracy or quality decision making. This requires not just access to available information but proper processing, interpretation and integration of that data. Critical is the consideration of multiple options and perspectives at all stages and there are a myriad of reasons why people do not do that. Defective decisions come from poor information search, selective bias in processing the information, a lack of considering alternatives, a failure to examine the risks of the preferred choice and a rush to judgement (Janis and Mann 1977). In short, the selection, interpretation and integration of information is biased.*"Nemeth (2012)

Therefore in conclusion to Nemeth's findings, the best practices to making any effective, quality decision are related to an unbiased judgement which is based on the full comprehension of all the available information surrounding the judgement. As with Asset Management Decision-making, which is typically undertaken in parallel with Strategic Planning the key to developing an optimised Asset Management Plan lies in the process set forth in the decision-making process.

3.4.3 Asset Management Strategy and Planning

Within Asset Management Strategy and Planning lies the core to the Asset Management activity required to develop, implement and improve Asset Management within an organisation (IAM, 2014). The deliverable of this group, as highlighted by (IAM, 2014), is a plan or strategic implementation document which creates a road map aligned to that of the organisation. This plan concerns the assets to be managed within their asset life cycle. Typically an example of such a plan is the Asset Management Plan or a Strategic Asset Management Plan (SAMP). At the root of this document lies the organisation's external and internal undertakings that are relevant to its core purpose,

affecting its ability to achieve the intended outcomes, which is not limited to the management of its asset management system. The SAMP should therefore be aligned to, and consistent with, the organisational objectives.

Furthermore, embedded within the concept of an SAMP is the notion of planning a structure to govern the full life cycle of any asset within the organisation Campbell *et al.* (2011). This practice of Total Life-cycle Asset Management (TLAM) focuses on the means in which assets are planned for, ustilised, maintained and eventually disposed of. Figure 3.7 shows the TLAM framework developed by IBM, which breaks down the life cycle of assets into discrete phases of activity Campbell *et al.* (2011). By creating a TLAM organisations create the ability to analyse their asset portfolio, with an elaborated insight into asset classes and systems integrated between various assets. It is within this awareness that organisations are able to make decisions and define asset strategies across the entire life cycle. It is within this depicted TLAM framework in Figure 3.7 that the eight life-cycle phases of use and planning, each has its own supporting financial management and technological attributes to consider in the SAMP.

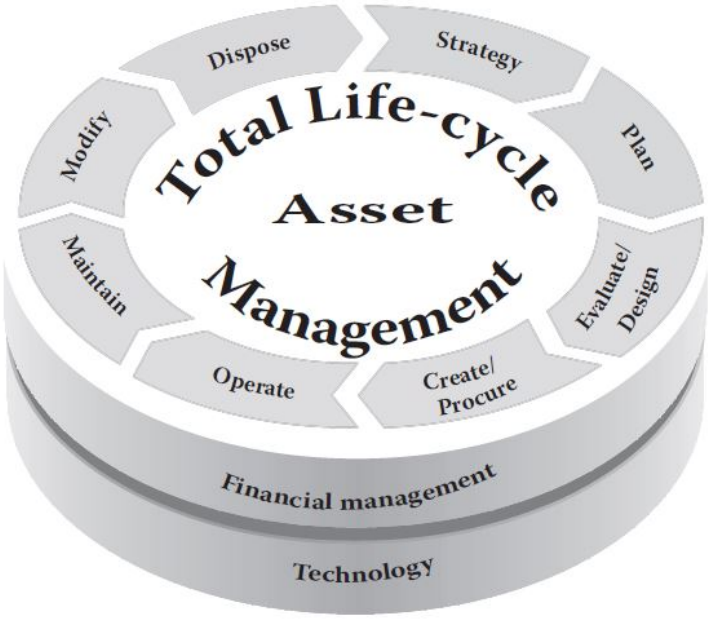


Figure 3.7: Total Life-Cycle Asset Management

Adapted from Campbell et al. *(2011)*

Furthermore in accordance with ISO 55001, a Strategic Asset Management Plan (SAMP) is derived from the organisational strategy, where the SAMP may be contained in, or may be a subsidiary plan of, the organisational plan (ISO55000, 2014). To illustrate this principle, Figure 3.8 depicts how the SAMP is the connection between the organisational environment and the asset management plan, where the SAMP is a basic starting point in implementing the Planning, Support, Operation, Evaluation and Improvement processes as set forth by the ISO55000 standard.

It is within this planning process, that the asset management plan takes shape and actions to change are constructed to initiate the objectives set forth by the leadership of the organisation. It is here where the SAMP is continually improved by feedback from an improvement process feed backwards from an operational and support process to provide line of sight for those involved in the organisational goals and objectives. This line of sight is an essential concept for effective asset management as it constitutes the golden thread of rationale which ultimately justifies every asset management activity the organisation undertakes (IAM, 2014).

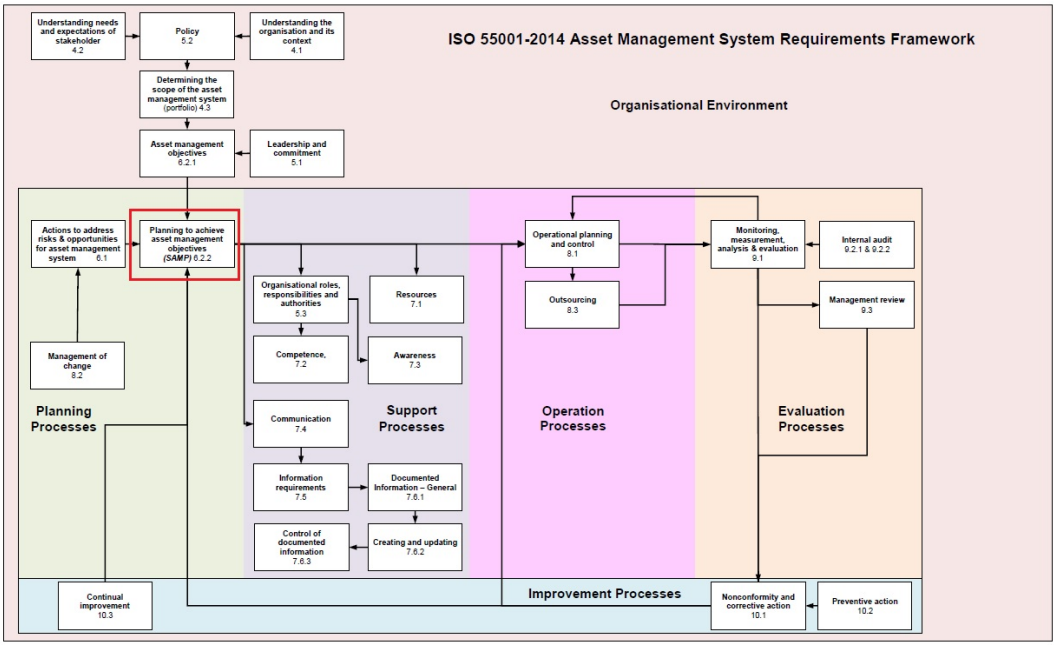


Figure 3.8: ISO55001-2014 Asset Management System Requirements Framework

Adapted from ISO55000 (2014)

It therefore with reference to the entire asset management plan where the asset management strategy and planning is created to describe the long-term

approach to management of the physical assets. An asset management strategy will typically include; AM objectives, Key accountabilities, decision-making criteria, development of asset information and asset management structures (GFMAM, 2014). It is within this plan that strategic statements are set forth describing the current and future service levels of the organisation and how it is planning to deliver, and the current and future AM capabilities that the organisation needs in order to sustainably deliver predetermined outcomes.

3.4.4 SAM strategic execution within PAM approach

It is within the focus areas as set forth by the anatomy of asset management (IAM, 2014) where the field of SAM aims to contribute value. When considering that the Asset Management Strategy and Planning is a basic starting block in the SAMP, it is important to realise that within this plan, the Asset Management Decision-making criteria are structured with respect to achieving objectives set forth in the asset management plan. Therefore to comprehensively improve the SAMP, attention should be placed on the need to make an effective and quality decision, where Asset Knowledge Enablers/Asset Information are the basic requirement. Within this fundamental building block, information needs to be captured in an unbiased manner which reflects accurate and real-time data that can therefore offer the best possible results to improving the SAMP and hence effectively the asset management plan. Therefore the value contribution of SAM will be fully comprehended once a case study has been deliberated within the succeeding chapters of this thesis.

3.5 Proposed SAM Implementation

Considering the contribution of this thesis towards practically applying the concept of SAM, this section focuses on existing models or frameworks which are related to the application of technologically driven tools which assist organisations with respect to strategic execution in gaining foresight toward business operations. As literature is sparse regarding the application of SAM, literature regarding the implementation thereof is also limited, therefore the premise of technology implementation is used as the basis for conducting research toward SAM implementation. Concepts such as *Technology Change Implementation*, *Technology Management*,*Technology Foresight*, *Technology Roadmapping* are concepts which are further explored to establish a basis for an implementation methodology. These strategies are therefore inferred upon SAM in order to propose an implementation model.

3.5.1 Technology Change Implementation

In the introduction of new technology, there are several factors that concern combinations and variables which can be used to predict success. Looking across different organisational settings, the combination of these factors and variables affecting successful implementation is inherently diverse. The concept of implementation, according to Goodman and Griffith (1991), is itself a metaphor of a complex changing environment where internal and external driving forces create ambiguity, where cause and effect relationships are difficult to pinpoint and furthermore discern. As a result the concept of technology implementation research is unlikely to develop a contingency theory which would be robust across all technologies and capable of dealing with the complexities of implementation. Therefore Goodman and Griffith (1991) focused on selecting a small number of processes, and used them to conceptually organise why implementation works or does not work in a specific setting. Goodman and Griffith (1991) developed a process-oriented theoretical approach which is used for the comprehension of implementation of new technology. In this process approach Goodman and Griffith (1991) described five processes which are conceptually related to the successful implementation of new technology namely;

1. Socialisation
2. Commitment
3. Reward allocation
4. Feedback and redesign
5. Diffusion

The approach used by Goodman and Griffith (1991) within their research led to discovering these components which are important to managing the social changes which technology implementation inevitably has on an organisation. Regarding the different levels of analysis, Goodman and Griffith (1991) have found that in particular, both individual and organisational aspects of implementation were important to the successful implementation of new technology. In a dynamic sense their analysis generated what they refer to as a *time-phased hypothesis*, which refers to the emergence of the processes and success criteria required over time. It is in respect to understanding the similarities as well as the differences between objective and social constructions of technology, that is important for understanding successful implementation. The aforementioned five processes provide a theoretical approach to understanding the various differences which are instrumental to applying change.

The interrelationship of each of the five components is regarded as a key driving force toward understanding as well as applying the implementation process. Integrated within these five elemental components lie the following four aspects which contribute to measuring the success of the prescribed implementation. The four measures of implementation success include;

knowledge embedded within the vision of the organisation, this success measure refers to the information held by different constituencies within the organisation on how to operate, troubleshoot, and redesign the technology

behaviour/utilisation refers to the performance with respect to the vision of the organisation including activities, for example monitoring, that the individual does with respect to the technology or levels of utilisation of the technology

attitudes refers to how different constituencies express positive or negative feelings about the implementation

normative consensus refers to the extent to which there is consensus about performance strategies and about the value of this new technology

Goodman and Griffith (1991) continued to describe each of these processes and tools of measurement in detail, where they highlighted the necessity for feedback and redesign processes as being critical to successful implementation of new technology. Goodman and Griffith (1991) also discussed alternative structures for generating this feedback process where formal and informal mechanisms are required to utilise the information gathered and reimplementing the redesign process. According to Goodman and Griffith (1991), it is with regard to this feedback of information that the true commitment process will take place over time. The concept of recommitment requires different mechanisms where various sources of commitment e.g. social norms versus rewards, affect the role of commitment in influencing implementation success.

The researcher recognises the impact that social constructs such as change management would have on the successful implementation of SAM. With respect to further contributing research towards the implementation of SAM, the focus of this research is regarded as a holistic framework, of which change management is a single component to successful implementation, where other factors will be further deliberated.

3.5.2 Technology Management

Cetindamar *et al.* (2010) considered Technology Management(TM) as a paradigm which inhibits dynamic capabilities, and he continues to describe this paradigm

as *the ability to reconfigure, redirect, transform and appropriately shape and integrate existing core competencies with external resources and strategic and complementary assets to meet the challenges or rapidly changing competition and imitation* (Cetindamar *et al.*, 2010). With respect to this definition Cetindamar *et al.* (2010) continues to describe three main reasons why the term dynamic capabilities is an appropriate means to understanding TM. These three concepts include;

1. It is not specific technological innovations but rather the capability to generate a stream of product, service and process changes that matters for long-term firm performance.

2. It is possible to observe the dynamics taking place in the organisation of firms, since the unit of analysis is the capabilities.

3. Dynamic capabilities theory considers the market or product as objects of strategic reconstruction and thus emphasises the key role of strategic management in appropriately adapting, integrating and reconfiguring internal and external organisational skills, resources and functional competencies towards a changing environment.

Therefore considering that TM is the management of technological capabilities which can be used to shape and accomplish the strategic and operational objectives of an organisation, the question becomes how to implement TM. Kearns (2004) describes this implementation with respect to six interrelated facets which impact TM and the implementation thereof. These facets are displayed in Figure 3.9 and are refereed to as Technology Evaluation, Product and Process Integration, Planning, Implementation, Training, and Change. Each facet is an important area as an isolated concept however contributes to the larger goal of technology management, where from a systems perspective it is clear that these facets are also interrelated aimed at the effective implementation of TM.

Kearns (2004) continues to conclude that overall, TM is building an organisation that is fit for today as well as tomorrow, where this organisational fitness is often achieved through making changes in business operations, which frequently involves the use of new technology. These technologies include information systems which offer the ability to make operations more efficient, cost-effective and offer overall improvement due to the reduction in redundant work, standardising operations, and maintaining records for both documentation of past work and references for future opportunities.

The terminology provided for TM definition highlights its possible relation to SAM and is therefore considered a starting point or basis when considering

Figure 3.9: Factors Influencing Technology Management

Adapted from Kearns (2004)

the successful implementation of SAM as a new technology. This leads to the question of how can TM be implemented, which will be discussed in the following section 3.5.3, where implementation methods include road mapping and technology forecasting as existing research methods.

3.5.3 Technological Forecasting

Hussain *et al.* (2017) discussed the need to map the future of new technology using a concept, technology foresight, which according to Hussain *et al.* (2017) is a well established discipline, practised with popular foresight methods such as road-mapping and scenario planning. Hussain *et al.* (2017) contribute to this notion of technology foresight by conducting extensive research into the various practices, highlighting the limitations and beneficial aspects of each method. Hussain *et al.* (2017) propose the combination of these foresight methods into specific model referred to as *scenario-driven roadmapping*. This model differs from existing technology foresight methods *"utilising scenario planning first to identify plausible images of the general environment and then using the scenarios for technology roadmapping. Secondly in taking advantage of 'flex points' critical developments which would signal transitions along particular pathways, to create a 'radar' to support effective monitoring of the environment over time. This new combined method takes advantage of the strengths of both methods, while addressing their limitations."* (Hussain *et al.*, 2017).

Considering the scenario-driven roadmapping approach as presented by Hussain *et al.* (2017) in Figure 3.10, this model illustrates the practical implementation of TM and will serve as a framework for the emerging technology presented by SAM which is further discussed in section 3.5.4.

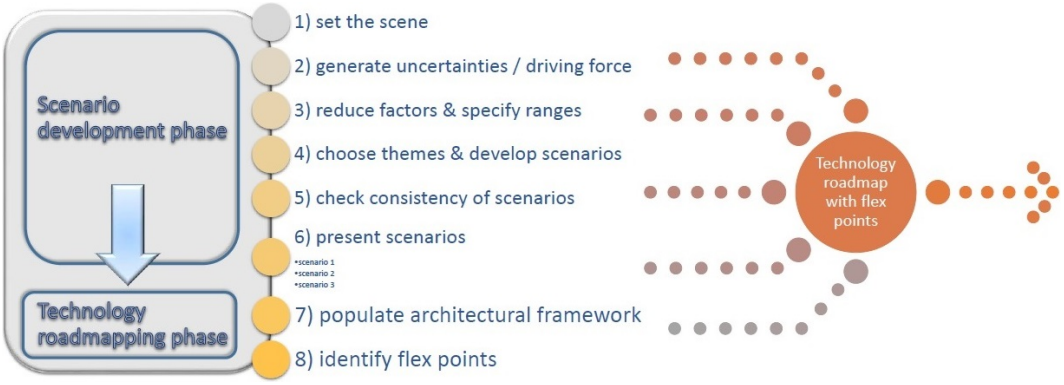


Figure 3.10: Scenario-driven Roadmapping

adapted from Hussain et al. *(2017)*

3.5.4 *Inferenced* SAM Implementation

As described in Chapter 2, SAM is an emerging concept related to AM, however, it is further related to other emerging ideas such as big data and IoT described in section 2.4.1. However these concepts have sparse literature containing the implementation of these emerging theories. Therefore with reference to the established models of TM and the implementation thereof, the proposed implementation of SAM is inferred from existing literature described in this section 3.5.1, 3.5.2 and 3.5.3 to be combined with a model identified by Holdowsky *et al.* (2015) for implementing IoT. This model, however, is not substantiated in any published literature, therefore it is regarded as a white paper research, and potentially not peer reviewed. The researcher acknowledges this article cannot be used individually to substantiate concepts as set forth in existing literature however the notions presented by Holdowsky *et al.* (2015) are such that, these ideas resonate with certain criteria as established within Chapter 2 of this research. Therefore the model as depicted by Figure 3.11 is considered an appropriate concept which can be added to established literature to create an appropriate model for SAM implementation.

The basic premise of the information loop as presented by Holdowsky *et al.* (2015), is a cyclical value-adding model where conversion is established within the loop from machine intervention to real-world decisions affecting overall value contribution. Considering the external actions of the loop namely; act, create, communicate, aggregate and analyse; these actions are affected by the basic technological building blocks, which can be referred to technological enablers, which assist the information transfer between actions. From the basic sensory collection of raw data, converted to a digital language within a network, this information is then sorted and stored on a central platform enforcing certain criteria and standards to be implemented. Once this organised information is accessible, it is applied to preconceived knowledge criteria which are used as a reference to obtain an augmented intelligence which ultimately leads to a value-contributing decision or to augment behaviour. These concepts elaborated within Figure 3.11 are closely related to the theory discussed in section 3.4.1, where Figure 3.6 is used to illustrate the progression of asset information to achieve greater asset wisdom and understanding. Utilising this greater asset wisdom also becomes a valuable tool for AM decision-making, implemented within an AM strategic plan as discussed in section 3.4.3 and section 3.4.4.

It is important to notice that within the centre of Figure 3.11, Holdowsky *et al.* (2015) add more information to their model; where concepts of magnitude, risk and time are identified. These concepts are fundamental premises which need to be established before the model can be implemented within a working environment. These factors relate to specific criteria, used to establish

the focus as well as limitation of the model, where resources such as time and money apply.

Each of these terms needs to be considered individually before the application of such a model can be considered, where these factors influencing implementation are addressed as follows. The term magnitude relates to the overall size and infrastructure of the IoT implementation; where the scope, scale and frequency of the information to be collected needs to be determined. Specific items need to be targeted, where the concepts of risk and time also affect this decision process. Furthermore, the risk of the entire model needs to be carefully considered to either mitigate certain aspects which may be conceived to have a greater risk (considering accuracy and reliability of information), as well as address areas where risk is introduced by implementing the model, such as network security. Lastly, the consideration of time is an important factor, where latency and timeliness need to be considered when supplying information to the appropriate end users and how a possible delay can influence the overall risk and magnitude of the system. These factors are interconnected and should therefore be primarily considered before such a model can be successfully established.

Concerning the information loop as presented by Holdowsky *et al.* (2015), it is important to recognise the flow of information which grows from a collection phase and ultimately results in an action phase. This action phase is what leads to the value contribution within an organisation. By initiating a response to the information collected, this allows the continued successful maintenance or enhancement of a physical process, event or state which can, within an established strategy, positively contribute to achieve a desired end result. It is with respect to this value loop presented by Holdowsky *et al.* (2015), in combination with the predefined AM theories, that an appropriate framework for implementing SAM can be constructed.

With respect to the literature presented in this section, a proposed framework, based on the collective contributions set forth in section 3.5, will be presented for a SAM implementation. The proposed implementation model incorporates the data collected and analysed, which is then presented to corporate management to validate whether the model is appropriate and also whether it can contribute to industry best practices.

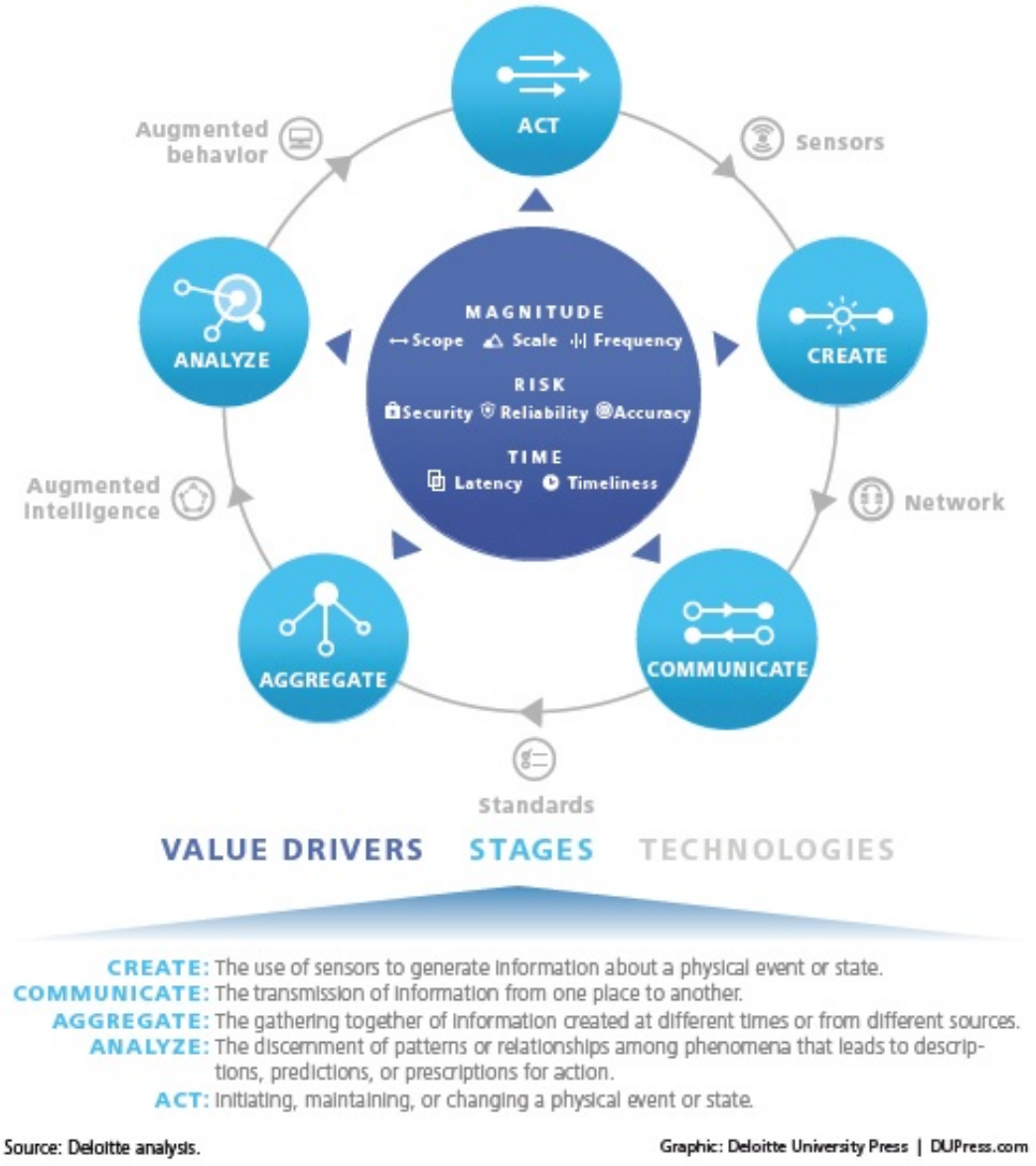


Figure 3.11: Information Value Loop for IoT Implementation

Extracted from Holdowsky et al. *(2015)*

3.5.5 Policy Frame Work Analysis

Having established the technical criteria required for the implementation of a SAM policy, general literature regarding the creation of a policy frame work will be further investigated within this subsection. In order to ascertain the theoretical requirements which should be established, research from the "Policy Studies Journal" will be utilised in order establish the ideal criteria required to create an effective policy framework.

According to Ostrom (2011), "*the development and use of frameworks are the most general forms of theoretical analysis. Frameworks identify the elements and general relationships among these elements that one needs to consider for institutional analysis and they organize diagnostic and prescriptive inquiry. They provide a general set of variables that can be used to analyse all types of institutional arrangements*"

From this definition of a policy framework implementation, as elaborated by Ostrom (2011), it is evident that the use of policy frameworks is aimed at establishing elements within an institution which can be used to organise the application of these elements through a predetermined prescriptive inquiry. Therefore one of the key factors to take into consideration is that through the creation of a new policy framework, existing prescriptive inquiry are not altered or set aside. Therefore to implement a new policy framework within a corporate environment, similar to this study which is conducted in MCSA, existing policy frameworks need to taken into account whilst establishing a new policy which incorporates SAM implementation.

Further to Ostrom (2011)'s definition, a policy framework is considered an established concept used to alter human behaviour as prescribed within the document created. Furthermore frameworks provide a "metatheoretical language" which is created to identify the universal elements, or specific components that any theory relevant to the same kind of phenomena need to include. Hence an infrastructure is provided in which the elements are established to operate in, where a key part of the framework is the identification of an action situation and the resulting patterns of interactions and outcomes.

Further utilising the research of Ostrom (2011), a policy document related to the application of SAM, specifically within the private healthcare industry is further investigated within Chapter 5. This policy document highlights the specific elements relevant within the framework where further prescriptive inquiry is established regarding the actions and resulting patterns to be created, whilst still operating within the exciting MCSA framework.

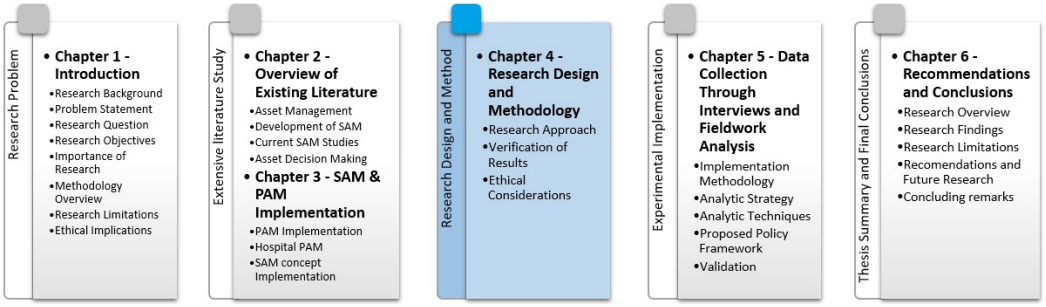
3.6 Chapter Summary

As per the theoretical implementations discussed in Chapter 2, Chapter 3 clearly illustrates the industry best practices of methodologies applicable towards implementing PAM. An in-depth investigation into the implementation of PAM in the hospital environment was also presented as per the guidelines of the WHO. It is within this basis that AM, as defined by the PAM context, is clearly portrayed as a management-based field of study which incorporates

human operational structures for managing people who manage physical assets IAM (2012). AM therefore supersedes asset maintenance and requires the buy-in of management to incorporate AM into organisational strategy whereby implementation resides in asset-related strategies as well as within the operational organisational structures IAM (2012). Therefore dysfunctional information exchange and poor decision-making, marks the primary constraints in PAMSE (Baum, 2012), and shows that SAM stands a chance of discerning problems in these domains. The implementation of SAM was also considered where strong inferences were highlighted to TM and the basis for a SAM implementation framework was established.

Chapter 4

Research Design and Methodology



Chapter Aims:

Having established the foundation for this research within PAM and highlighting the framework for PAM implementation within the private healthcare industry, the need for this research in applying SAM has also been introduced. With this basis established, this chapter now aims to outline the research methodology chosen for this research. Taking various techniques into consideration, this chapter outlines the methodology related to a case study research design, using interviews to collect data and analysing this research within an explanatory building analysis approach based on pattern recognition from data gathered.

Chapter Outcomes:

- Deliberate research methodology with specific reference to appropriateness of the method chosen
- Explain the verification of the reliability and validity of research design
- Examine relevant ethical considerations with respect to the methodology selected

4.1 Chapter Introduction

At the foundation of this research is an intricate blend of establishing a relatively new research concept namely SAM, as well as the research problem concerning risk mitigation within the private healthcare environment. A qualitative research paradigm has therefore been identified as a suitable means to address the focus area of this study which aims to explore this new concept as well as investigate an in-depth case within the private healthcare sector. As pre-emptively discussed in Chapter 1, this study will be dealt with in a two-part approach where the specific research techniques each have their own contribution toward addressing the research questions and furthermore fulfilling the research problem. Before the two approaches are further discussed, a review of the research problem needs to considered to provide clarity regarding the research methodology rationale. The rationale of this research study is focused on exploring the qualitative aspects of enhancing the management of operating theatres within operational and corporate management structures. This research design aims to create a procedure to investigate if incorporating technological communication methods to produce asset knowledge enablers, allows for the possibility of better management decisions being made. The exploratory nature of this study should also incorporate the input of management structures, namely corporate and operational management within various hospitals, to provide collaboration in generating a possible comprehensive solution.

With this research paradigm in mind, it is important to note that various tools and techniques are available which can be utilised to address the problem statement. However these chosen instruments need to be verified, where the identified method, the data gathering techniques and analysis also need to be independently validated. The available sources of evidence within this case study research include archival records from a CMMS system as well as the ability to converge and gain feedback from technical managers and managers within corporate office, acting as technical experts within the field. The intended focus and ultimately the conclusion of this research design, would be to provide an encompassing solution or feedback, where the contribution of the study is aimed at addressing the research problem. Furthermore the research design is aimed at considering two facets of the study, firstly addressing the research questions, and secondly establishing the validation process. Considering that the research has already been defined as case study research, the research design process as interpreted by Yin (2009), who specifically addresses case study research design and methods, will be used as a predominant framework for implementation. Building on this approach, as well as using other sources, the research design will be further defined within this chapter to explicate the employment of the necessary avenues followed.

4.2 Research Approach

The research approach can be viewed as the strategy which needs to be followed to conduct and present the research in a structured manner. The research approach according to Bryman and Bell (2014), is defined by the research design and the research method which are often misinterpreted. The *research methods tend to be associated with different kinds of research design. A research design provides the structure that guides the use of a research method and the analysis of the subsequent data.* (Bryman and Bell, 2014). Bryman and Bell (2014) continued to further define a research design as a *framework for the collection and analysis of data.* The choice of the research design reflects decisions about the importance attached to the various dimensions of the research process. Therefore the research design can be considered a plan or guide used to facilitate the research process, whereas the research method is defined as the tool or technique used to gather the information.

Within the research approach lies the fundamental research methodology as affirmed by Cresswell (2009); Edmunds and Kennedy (2012); Bryman and Bell (2014), namely Qualitative, Quantitative and the mixed methods approach. Cresswell (2009) suggests a "framework for design" which utilises three elements within these approaches; The interconnection of Worldviews, Strategies of Inquiry and Research Methods; as depicted by Figure 4.1. This framework, according to Cresswell (2009) is useful in order to justify which research design approaches are the most suitable to the research being investigated.

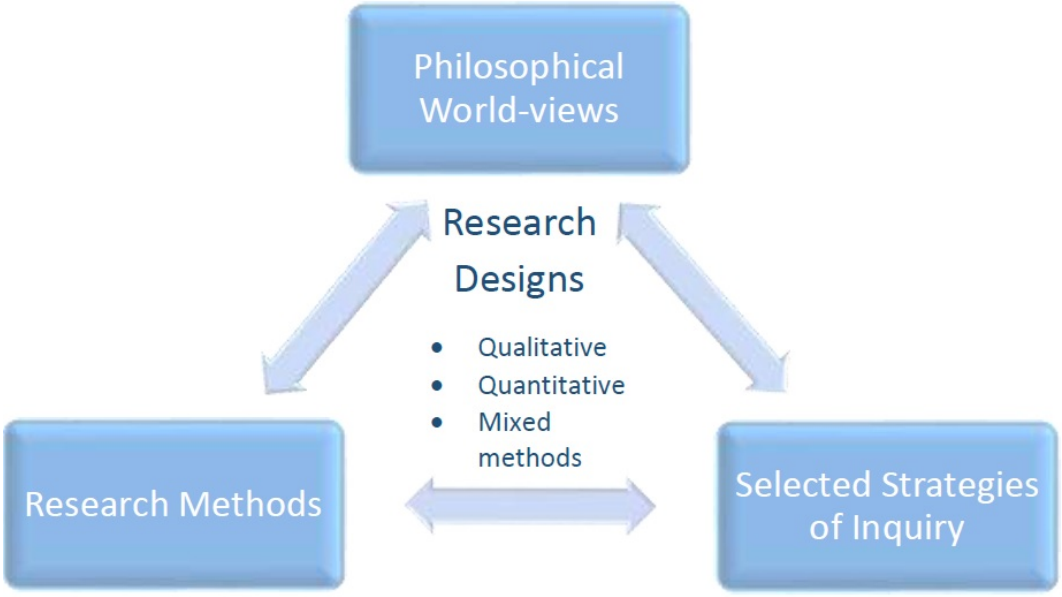


Figure 4.1: Research Design Framework

Adapted from Cresswell (2009)

Centre to this framework lies the research design methodology, where according to Newman and Benz (1998) these two approaches, namely quantitative and qualitative, are not in contrast to each other but are rather two ends of a continuum. Where research should lean more to either end of the scale between one of these two approaches, where mixed method falls directly in between these two categories. Therefore it can be said that research tends to be either more qualitative or more quantitative and not conclusively one or the other. The decision however to emphasise one specific research approach above the other is determined by the research agenda which is under investigation. Cresswell (2009) highlights the following design constituents, depicted in Table 4.1 which builds on the research design framework.

Table 4.1: Research Design Constituents

Constituents	*Description and content*
Research Designs	Qualitative, quantitative or mixed methods, where these elements are incorporated within an overlapping of research methods, philosophical wordviews and strategies of inquiry
Research Methods	Questions, Data collection, Data analysis, Interpretation, Write-up and Validation
Philosophical Worldviews	Postpositive, Social construction, Advocacy/ participatory and Pragmatic
Strategies of Inquiry	Qualitative strategies, quantitative strategies or mixed methods strategies

Within the research constituents, as identified by Cresswell (2009), he goes on to further emphasise that the exploratory nature of qualitative research can be a benefit where a lack of existing research is prevalent within the respective field. It is within this regard that qualitative research can be used to supplement the few publications of SAM, to understand the obstacles that are identified concerning problem areas in PAM strategies. This qualitative research agenda can include the collection and assessment of subjective data such as white papers and organisational interpretations of SAM to generate open-ended questions and subjective arguments which creates a basis for SAM research.

In contrast to the qualitative approach, quantitative research involves a research method aimed at assimilating objective data which is close-ended and based on numerical accuracy where data can be analysed using statistical procedures Cresswell (2009). Considering that SAM is a new concept and requires qualitative research to justify assumptions, the qualitative research method focuses on data which is exploratory in nature allowing the researcher to probe participants for quantitative feedback. This allows, to a small extent, data analysis which can be quantitatively examined to expose patterns and concurring information within the data collected to substantiate conclusions within the research study. With this coincidental information, the study can continue to qualitatively extrapolate the research findings within the group as well as what may be appropriate within other applications, sectors and industries. The research results from the quantitative data analysis are validated by reviewing data within a validation process which allows a secondary subjective group of experts to confirm or deny results that coincide with the basis of data that was formed in the original subject of analysis.

4.2.1 Philosophical Assumptions

The term philosophy describes the use of abstract ideas and beliefs that inform our research (Creswell and Poth, 2017). According to Cresswell (2009), the concept of philosophical assumptions when examining research and using theories, should be a preliminary consideration before reviewing literature. He states that researchers need to consider their philosophical assumptions before they begin to even design their studies.

> *Whether we are aware of it or not, we always bring certain beliefs and philosophical assumptions to our research. Sometimes these are deeply ingrained views about the types of problems that we need to study, what research questions to ask, or how we go about gathering data*(Creswell and Poth, 2017).

With these philosophical assumptions in mind it is important to consider the specifics of this study. It has been identified that this study involves both a new focus area of research, predominantly with SAM being a poorly defined concept, as well as the multifaceted nature of this study where the research problem overlaps the operational and strategic corporate management. Therefore the research problem can be considered complex due its impact within the organisation as well as with respect to the people involved. Therefore regarding the area of influence which cannot be fully consolidated within a quantifiable formula or expression, this study lends itself toward a qualitative research construct where various participants can be involved to offer their input in clarifying the complexity of this research which also meets the fol-

lowing criteria as specified by Cresswell (2009) regarding qualitative research approaches:

- Exploration and understanding the meaning of individuals or groups that ascribe to a social or human problem
- Process of research involves emerging questions and procedures
- Data typically collected in the participant's setting
- Data analysis inductively building from particulars to general themes
- Researcher making interpretations of the meaning of the data
- Final written report has a flexible structure
- Those who engage in this form of inquiry support a way of looking at research that honars an inductive style, a focus on individual meaning
- Importance of rendering the complexity of a situation

Using the criteria as elaborated by Cresswell (2009), these concepts are true concerning the proposed research. Starting with the premise that SAM is a new and complex problem, this leads to a research requirement which is able to yield new insights by fully exploring the nature of the problem at hand. Where qualitative research is indeed focused on the exploration of the individual's insight, conversing a social or human problem whereas the information is also collected in the participant's setting to fully comprehend the complexity of the research problem. Due to the fact that the research is not confined to creating fixed sets of information patterns with respect to human behaviours, instead it is focused on making sense of the human experience in the context of the current working environment. This process of research also allows the merging of questions and procedures which encourages the analysis of information to be inductive, building from particulars first hand experience with respect to the problem and investigating a solution which fits the environment of the participant. Rather then making interpretations of the meaning of the data and implementing the final results, this research allows for a flexible structure, incorporating various fields to fully capture the complexity of the situation.

Furthermore the research area does not consist of fixed information with clear-cut answers which can be validated to a list of proven ideologies. Instead the feedback obtained from the participants will lead to complex discursive replies. Therefore the responses should be contextualised within the environment in which they were captured thus a research methodology is required to fully comprehend distinctiveness of the individuals' responses.

Within this criteria, the proposed research strongly emanates with the central themes of a qualitative study as listed by Cresswell (2009). The philosophical assumptions are embedded within this interpretive framework that qualitative researchers use to conduct a study. This framework for understanding philosophical assumptions lies in the use of abstract ideas and beliefs that impact the research from the researcher's personal understanding. It is here that the overview of the process of research compiled, helps to place philosophy and theory into perspective in the research process (Denzin and Lincon, 2011). Furthermore Denzin and Lincon (2011) consider the philosophical assumptions by using the following key concepts (ontology, epistemology, axiology, and methodology) as premises that are folded into interpretive frameworks used in qualitative research. McLaughlin (2003) and Creswell and Poth (2017) included a fifth philosophical assumption, the rhetorical premise and elaborated the application of each of these terms in Table C.1.

When considering the various philosophical assumptions, it is important to realise the stance of the researcher regarding the involvement with participants and the research being conducted. In this specific study, the research being conducted is within the researcher's place of employment, where various participants are known personally to the researcher. Therefore in terms of the *ontology* assumption, the researcher assumes the nature of reality as being subjective and multiple where participants are quoted directly to provide varying evidence. The assumption of epistemology is also valid in the view that the researcher is directly involved with the event of this investigation where there is also direct interaction with the participants. This allows for focus on the outcomes of the research as well as being able to interpret the participants' insight with personal understanding into the research problem. As a further result of this value contribution, the researcher recognises the value-laden and bias present in the research where the researcher's own interpretation is included in an axiological philosophy assumption. By conforming to this assumption, personal interpretations can be openly discussed in conjunction with interpretations of the participants. To offset this personal bias, validation is conducted in such a manner to verify the process and analysis of the research conducted.

Therefore in conclusion of the philosophical assumptions discussed, the research logic as described by Cresswell (2009) which has specific reference to qualitative research, as illustrated by Figure 4.2. This concept highlights a bottom-up inductive process relevant to this study, where this process flow illustrates the logical progression which the researcher follows from gathering data, the thorough analysis of data leading to usable information and the resultant conclusion from the responses. Also considering the research process for qualitative research is emergent Cresswell (2009), it is important to consider

that the means of addressing participants cannot be tightly prescribed. Phases of the process may change or be altered as the researcher begins to collect data. As an example, the questions may change, the forms of data collection may shift, and the individuals studied or sites to be visited may be modified. However, within this specific study, although a structured questionnaire is utilised to address participants, their feedback is independent, originating from various locations within the same corporate group. Although some questions are open-ended, the responses to questions need to be analysed collectively to gain a general understanding of the research problem. The validation of the study and the analysis of this information is conducted through a face validation to confirm whether this prescribed process is accurate in order to reflect the understanding of the research problem. The face validation procedure will be further discussed in section 5.5.

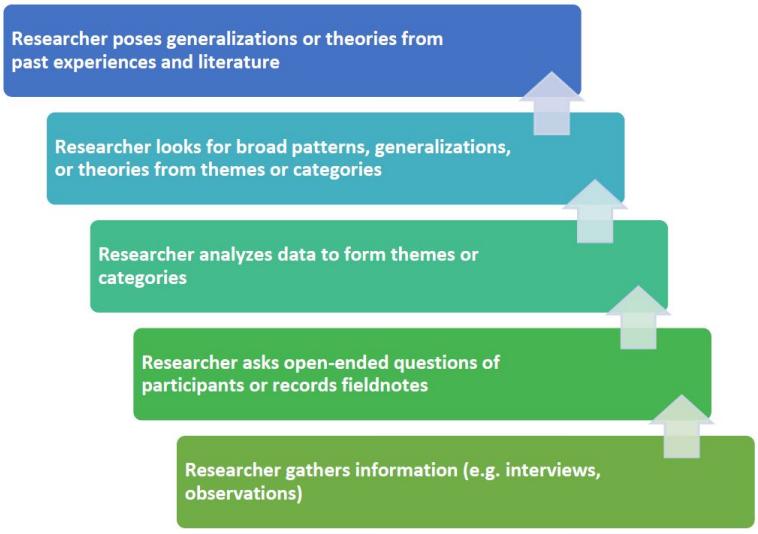


Figure 4.2: Inductive Logic of Research in a Qualitative Study

Adapted from (Cresswell, 2009)

4.2.2 Philosophical Worldviews

Referring back to Table 4.1, Cresswell (2009) also describes what he refers to as "Philosophical Worldviews" which can be defined as "a basic set of beliefs that guide action". Cresswell (2009) goes on to further describe other variations and terms applicable to this concept including; paradigms, epistemologies and ontologies or broadly conceived research methodologies. Cresswell (2009) refers to these worldviews as "a general orientation about the world and the nature of research that a researcher holds. The worldviews are shaped by the discipline area of the student, the beliefs of advisers and faculty in a student's area and past research experiences. The types of beliefs held by individual researchers

will often lead to embracing a qualitative, quantitative, or mixed methods approach in their research". There are four worldviews as described by Cresswell (2009) namely; post-positivism, constructivism; Advocacy/ participatory (also referred to transformative/interactionism) and lastly pragmatism.

Considering the various philosophical worldviews, the identified viewpoint which guides the strategy of this thesis is the pragmatic worldview. Baum (2012) elaborates this worldview by stating that pragmatism uses "all approaches available to understand a problem, it places a special emphasis on the research problem rather than on methods". According to Cresswell (2009) this pragmatic worldview arises out of actions, situations and consequences rather than exemplary predefined conditions. Furthermore Cresswell (2009) confirms that "Pragmatism is not committed to any one system of philosophy and reality. This applies to mixed methods research in that inquirers draw liberally from both quantitative and qualitative assumptions when they engage in their research." The adoption of the pragmatic worldview is therefore the centre of the research approach for this thesis due to the research problem being embedded in the emerging field of SAM. The notion of SAM, although a complementary addition to PAM, does not have the required research literature to substantiate a completely solitary quantitative research approach. Therefore qualitative research is used to cross the existing boundaries within the field of PAM, to employing methods that have their roots in a newly focused discipline. Where the pragmatic worldview can be embraced to substantiate the concept that the researcher is a key instrument in qualitative data collection.

As elborated by Cresswell (2009), researchers themselves collect data through examining various sources and by interviewing a variety of participants. Within this research design, by creating a set interview protocol used as an instrument for collecting data, the researcher further utilises the information from an on the ground, personal perspective to inductively demonstrate patterns, categories and themes. Furthermore by a process of validation this research has a key independent secondary source, to either confirm or deny the correct utilisation of the research design which has originated form the relevant philosophical worldview as described within this section. The implementation of these processes will be further elaborated in Chapter 5.

4.2.3 Research Design and Strategic Approaches

According to Bryman and Bell (2014) a research design "provides the framework for the collection and analysis of data. The choice of the research design reflects decisions about the importance attached to various dimensions of the research process". With these factors in mind, the strategies of research design originate out of disciplines that flow throughout the process of research.

The general framework or characteristics of the design are related to the data collection, analysis, and writing. As further discussed by Cresswell (2009), the research designs focus the plans and the procedures of the research that extends the decisions from broad assumptions to detailed methods of data collection and analysis. It involves the intersection of philosophical assumptions, strategies of inquiry, and specific methods.

The overall research design considered as a strategic approach to the research being conducted, with respect to the philosophical assumption and strategy of inquiry presented in the previous subsections, enforces the qualitative research approach. This approach is in line with strategic responses to the complexity of the subject matter as well as the pragmatic world view followed for the data collection. Also regarding the case study as a strategy of inquiry, in which the researcher explores an in-depth process, as identified in the research problem, with its application by various individuals in the same position. The specific case study is also bounded by time, activity and the organisation in which is conducted.

The research methodology is further presented in section 4.2.4 which will further outline the proposed interview process as a means to collect the primary source of information from participants within the organisation. Regarding the research design with reference to the proposed strategic approach, the information available to the researcher will be retrieved from individuals within the organisation where the study is being conducted. Therefore due to this primary source of data, the research design should accommodate the research methodology in capturing the required information, whilst addressing the identified research problems. Furthermore the research design should also attend to an overall contribution in addressing the problem statement applicable to the environment from which it originated. Due to these defined criteria, as well as those further elaborated in section 4.2.1, the overall design and strategy is inherently qualitative in nature accommodating the source of information presented to the researcher allowing context to be captured from individual responses, where the findings also remain applicable to these individuals and may be further extrapolated to other industries as identified by trends and characteristics presented.

4.2.4 Research Methodology

Considering the preceding sections which established the constructs and reasoning for the type of research conducted, this section will focus toward the methodology of conducting the research within a qualitative research design methodology, as well as the reasoning behind utilising a case study design approach.

Cresswell (2009) defines a case study as a strategy of inquiry in which "*the researcher explores in depth a program, event, activity, process or one or more individuals. Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time.*" Expanding on this interpretation and continuing with the research design as stipulated by Bryman and Bell (2014) and Yin (2009), a case study design involves the detailed and intensive analysis of a specific circumstance or case. This case research delves into understanding the complexity and particular nature of the case. Yin (2009) also highlights the fact that this specific research design is suited for a study focused within a particular geographical location referring to an establishment, or more so pertaining to a single organisation.

Bryman and Bell (2014) provide another argument which sets apart a case study from any other research method, in the fact that the focus area of this type of study relates to understanding a bounded situation or system which is predefined to the creation of the research objective. The boundary of a case study is not always clear-cut between the case's functioning parts and the context in which it operates. Relating to this argument, is the boundary of this research study which is founded within private healthcare hospitals operating throughout southern Africa. This research concerning data which is to be collected from an operational basis, within specifically selected hospitals furthermore needs to be viable on a corporate level. The boundary of this research crosses certain standards and guidelines as set forth by corporate management influencing the operation of hospitals within the group.

Based on this observation, the boundary of the research problem therefore shifts away from the hospital itself, and surrounds the corporate standards concerning the infrastructure of the group's management of physical assets. It is however within the operational setting of the individual hospitals that the case is being researched, where participants are interviewed within a structured questionnaire to provide specific accounts applicable to their particular environment. These individual references help generate a detailed account of the complex nature of this study where further examination of the case becomes applicable to a corporate standard, appropriate to all hospitals within the corporate environment.

Concerning the methodology of the research to be collected, the interview process should therefore be managed using a structured and unstructured questioning process as a basis for the inquiry. Within the data capturing process, responses should also be consolidated to test the conformity of problems faced and well as implementation of existing applications to address problems. This method will allow the researcher to have control over the line of questioning

whilst still allowing the participant to provide personal input and information to their own historical experiences as advocated by Cresswell (2009) for conducting qualitative research. This structured interview process, as handled within the case study process, should also be considered within a single case or multiple case selection.

Yin (2009) proposes the selection process of a single case versus a multiple case study, where within each case exists either single or multiple embedded units of analysis. These units elaborate various sources of information which are available to the case. Given the fact that this study is related to a single organisation, focusing on the management decisions as prescribed by a corporate institution, this study lends towards a single case study analysis. Yin (2009) goes on to further define the rationale for a single case study being related to five varying concepts; critical test of existing theory, rare or unique circumstance, representative or typical case, revelatory and finally a longitudinal purpose. Considering these formats of single case study analysis, the most appropriate rationale involves a representative or typical case.

Using the rationale of Yin (2009), for a representative or typical case involves the investigation of a case from a representative of the case study. In this study, the technical manager reflects this representative embodying the typical experience from that specific hospital. Furthermore, regarding the research problem, this case also highlights the uniqueness of this research, where the research objective's aims describe the exploratory nature of this specific case and its relation to the concept of PAM being related to SAM. Lee *et al.* (2007) contribute to Yin (2009) by further promoting subsidiary case study rationale, stating that Yin (2009)'s list is limited by a positivist perspective. Lee *et al.* (2007) goes on to define descriptive case studies which "*are often used to expand on trends and themes already discovered by survey research*". It is within this research where these trends can be further elaborated to case studies which are contextually based, in terms of a "*generalization that constitutes a meaningful and convincing connection of the study with the real-world phenomena surrounding the case in question.*" (Lee *et al.*, 2007).

Yin (2009) goes on to further recommend a multiple case study approach over a single case study approach due to the fact that it allows the researcher to broaden the bases of resource and assists with validation between various cases. Due to the fact that the researcher is not able to come by participants within other organisations, this research is limited to the single organisation, hence a single case. However, to support an external validation process, the research and data collected are validated according to a validation process elaborated in section 4.3 within the verification of results. To validate the research design and methodology, it is proposed that specialists in the field from corporate

management will be further involved to retrieve their feedback of the research design and methodology. These technical experts' feedback will also be retried as part a the qualitative study with the case study research approach. It is with respect to the definitions provided by Yin (2009) and further clarifications of the case study method of inquiry which provides an ideal framework for conducting this research. Consequently these methodologies and analysis techniques are adopted to further this study, where the applied methodology is evident in Chapter 5.

4.3 Verification of results

This section examines the process implemented by the researcher to ensure that results obtained are reliable, trustworthy and hence validated toward an external process to ensure the correctness of the research conducted. Furthermore this section delves into the researcher paradigm-fit as well as the role and impact of the researcher with respect to collecting the data.

4.3.1 Validity of Research Results

Kidder and Judd (1986) defined four basic criteria for judging the quality of research designs, where these constructs are a common test for all social science research methods. These four criteria include construct validity, internal validity, external validity and reliability. Validity plays a vital role in confirming the credibility of the research as well as the dependability of the information presented, whereas reliability demonstrates that operations of the study can be repeated with the same results. The researcher is tasked with presenting evidence in a logical manner where statements made can be refuted or confirmed by other researchers following similar processes. Yin (2009) defines three principles used in conjunction with data analysis, which when combined with the various methods of collecting evidence will help deal with the problems faced by researchers in establishing a construct for validity and reliability with respect to the analysis of case study evidence. The three principles include; using multiple sources of evidence, creation of a case study database and maintaining a chain of evidence.

According to Yin (2009) the rationale for using multiple sources of information is embedded in the triangulation approach. This approach highlights the convergence of individual sources of information to concur on the facts being presented within the research. Yin (2009) highlights the fact that one of the greatest benefits of using a case study analysis approach lies in the ability to use multiple sources. Multiple sources of information allowed the researcher within this study to highlight the historical evidence presented in

the archival records with the behavioural experience identified within the interview data. Looking at these two sources, the converging line of inquiry is established to present multiple measures of the same phenomenon, led from different sources. This allows the researcher to corroborate between sources to create an accurate and convincing series of statements backed by the presented evidence. This method of utilising data triangulation assists in strengthening the validity of the research presented, where information from one source may be skewed in favour of a specific conclusion yet multiple sources converging to a singular fact or phenomenon represent convergence, improving the validity of the statements presented.

The case study database refers to the inclusion of independent raw data which needs to be presented to the reader for their own discretion. This information should be formal and presentable to allow other investigators to review the information directly and not be limited to the written case study report, modified and altered by the researcher. By displaying this case study database, the reliability of the evidence becomes more evident and findings drawn from the evidence can be reproduced by alternative investigators to confirm statements made by the researcher. To support the reliability of the case study, this evidence will be provided in the addendum to this research study, whereas case study reports and findings drawn from the evidence will be discussed in Chapter 5.

Considering this research in the light of a forensic investigation, the statements presented by the researcher need to be backed by evidence obtained either in data collection or from other established research. Thus the link or chain between the evidence and statement is a process which needs to be evident to an external investigator, who should be allowed to follow the trail from the initial statements presented within the research to the final conclusions and recommendations. Therefore the external observer should have the option to trace the chain of evidence, step by step, in either direction to substantiate the findings presented. Ultimately the case study chain of evidence is beneficial to both the researcher and the reader in providing clarity between the movement of the research from one part of the case study to another, where cross-referencing to methodological procedures and the resulting evidence allows both parties to universally concur on the research findings. The chain of evidence represents a standard in research which allows the reliability of the research to be confirmed through a universal process of investigation understood by all investigators. Results can therefore be replicated by following the same approaches, made evident in the process.

4.3.2 The Researcher-Paradigm fit

Cresswell (2009) advocates a self-disclosing researcher whereas an omniscient writer is not accepted with respect to the presentation of their qualitative research. In this regard it is necessary to understand the researcher paradigm in order to fully comprehend the interpretations founded within the worldviews of researcher, shaping the research provided. The researcher chooses to adopt a notion of reflexivity, where according to Cresswell (2009) this notion refers to a researcher who is conscious of the biases, experiences and values that is inferred upon the qualitative research due to their personal paradigm. The researcher should therefore acknowledge this personal paradigm, reflecting on this inference whilst conducting the study. Personal interpretation and insight of the literature and the participants within the study are also interconnected to this personal paradigm.

The researcher identified the case study research as an ideal way to capture multiple sources of evidence, where the basis of a qualitative study was preferred due the lack of satisfactory quantitative evidence and personal resources which could be used to substantiate the investigation and implementation of SAM as discussed within the Chapter 3, SAM implementation. The researcher could also not find any supporting literature to substantiate the concept of implementing a SAM system within the private healthcare industry. Therefore it is assumed this concept has also not been implemented before where an introductory qualitative analysis is considered by the researcher to further this field of research.

The researchers perceptions of SAM and AM are based from an undergraduate study in BEng(Mechatronic), where personal work experience with regard to automated engineering processes utilising SCADA and PLCs was the basis for implementing this study. The researcher also completed a certificate in senior management development, with an interest in understanding and attempting to resolve some of the complexities of management-related concepts within operational execution. The researcher is currently enrolled for a master's degree in engineering management, within Stellenbosch University's industrial engineering department, based within the AM division and is also receiving guidance from a study leader specialising in asset care research. Therefore due to the personal focus of the researcher, an inherent partiality has been created for expanding AM with respect to the concept of technological driving factors as the basis for making better management decisions as discussed within the construct of SAM.

The researcher is also permanently employed within the private healthcare sector, in the technical department of MC, which has culminated in the research pertaining specifically to the private healthcare industry. This is par-

tially due the availability of resources as well as access to participants within the study whose information is available and to some extent known to the researcher. Also, personal working experiences and conceived areas of improvement which have been identified by the researcher have led to wanting to improve the current standard as well as creating an opportunity for future research.

4.3.3 The role and Impact of the Researcher

As discussed by Cresswell (2009), the researcher has the primary function of conducting the qualitative research. The researcher is required to collect data, analyse and examine this data with respect to other supporting documents and observe participant's responses. The researcher is therefore seen as the key component within the research and should also assume multiple roles in order to assist the research in obtaining final recommendations which are achieved through an objective process.

The researchers' experience within the private healthcare industry as well as personal experience in technological driving factors with respect to SAM, is seen as valuable toward contributing to the research and steering the direction of this study. This experience is important as it represents the basis for the interaction between other participants within the research where their responses can be interpreted with personal understanding. This also allows the researcher to adopt the technique of objectively *asking questions* throughout the remainder of the study to enable the researcher to probe, develop provisional answers, oversee all responses and become familiar with the data.

However an alternative role also requires that the researcher is tasked to distance himself from his personal experiences in order to be sensitive towards the contribution of other technical managers and their understanding and experiences with respect to the implementation of AM within their environment, where some participants have many years' experience to contribute. The researcher also needs to be aware of their competencies as well as the fact that some participants may withdraw or provide inaccurate information when their implemented processes are critiqued. Therefore it is important for the researcher to distance himself from his own experiences to fully analyse the contribution made by the participants. This sensitivity will enhance insight into the day to day understanding of the operational environment and further contribute to data collected as well as the study as a whole.

The role of qualitative researcher is one that binds all the aspects of the research together. Apart from personal experience with the field of study, the researcher needs to be sensitive to the theoretical processes required of

a researcher. The theoretical sensitivity allows the researcher to interpret data according to the prescribed processes and frameworks of investigation as set forth by established and acknowledged research. This sensitivity grows with exposure to data allowing the researcher to become in harmony with the interpretations embedded within the data (Strauss and Corbin, 1998). This insight allows the researcher to see below the obvious "upper crust" of new data presented, to interpret the core value it holds with respect to the research in question. Both professional experience and literature are used to guide the researcher's source of sensitivity to gain greater understanding of participants' explanations.

It is evident that there exists an interplay between the research and researcher where the researcher is the primary instrument for conducting the research (Strauss and Corbin, 1998). As a result of the inferences of the researcher, it is deemed important to maintain a balance of objectiveness (refer to section 4.3.2) and sensitivity (refer to section 4.3.3) during the research analysis procedure.

4.4 Ethical considerations

This case study research is conducted within a corporate environment where data from various hospitals within the group is used as well as from participants employed within the group. Their opinions and experiences are also involved as part of evidence presented. In this research there is no ethical discrimination regarding personal and organisational feelings, beliefs, culture or experiences which are of concern to this study. Furthermore there are no known risks, inconvenience, discomforts, physiological stress or stigmatisation associated within this study.

This research study also adheres to all relevant ethical considerations, standards and policies concerning the scholarly and scientific research requirements as stipulated by Stellenbosch University. Ethical clearance has been provided by the ethical clearance committee, and all interviews have been conducted according to the ethical policies. For further perusal of ethical clearance, Appendix B.1 refers to the consent provided by MC corporate office to conduct research within the organisation, granted from the group technical operations manager. Appendix B.2 refers to the ethical consent form signed by participants conducting the research, where the ethical committee case reference number, which can be referred to for approval of this research is SUHSD004164.

The participants involved within this research study, their identities and personal details, documents and records are kept confidential and anonymous using pseudonyms to represent each respondent. Their contributions to the

findings are accessible solely to the researcher, supervisor and examiner of this study. All recorded information relevant to this study gained from interaction between participants is safety stored on a password-protected personal computer. Access to the information is restricted, and participants' information is kept confidential.

4.5 Chapter Summary

As outlined in the research approach in section 4.2, a summary of the research design and methodologies prescribed by Cresswell (2009) is presented in Table 4.1. With these predefined research design constituents in mind, a summary of the utilised research design and methodology is presented in Table 4.2. This table is used as a summary to conclude the research design and methodology as utilised within this thesis.

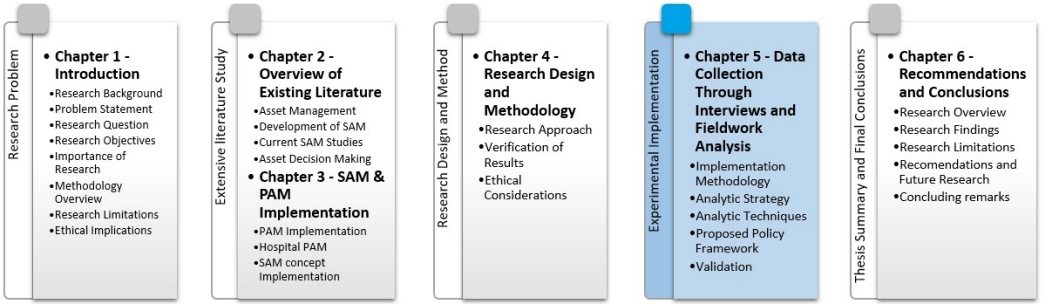
Table 4.2: Summary of the Utilised Research Design and Methodology

Constituents	*Description and content*
Research Designs	Qualitative approach is set as the basis to establish current operational issues. Furthermore quantitative data is utilised to a smaller extent as a separate source of evidence within the case study analysis.
Research Methods	Interviews in the form of a structured questionnaire are used in the data collection, including a secondary archival data source of information from the organisational CMMS. Data is analysed through coding techniques to group feedback. Interpretation is done comparing various sources of evidence where validation occurs with a face validation procedure to present final recommended write-up of research.
Philosophical Worldviews	Pragmatic worldview instead of focusing on methods, the researcher chooses to emphasize the research problem willing to consider various research approaches to understand the problem. Furthermore a reflexive worldview is also considered where the researcher is concious of biases and personal influences in research.
Strategies of Inquiry	Case study research, where research is conducted in an objective manner

In conclusion, this chapter therefore set out to construct a research methodology, which follows prescribed research techniques to ensure validity and reliability of the research. Various methods and final rationale was discussed for selection of the chosen methodology. Furthermore this research methodology is built from the foundation of the research problems as established in Chapter 1 which considered the problem statement and objectives. The role and impact of the researcher toward the research was also discussed as well as the inclusion of the ethical clearance which was obtained to conduct the research.

Chapter 5

Data Collection Through Interviews and Fieldwork Analysis



Chapter Aims:

This chapter is concerned with categorising data collected in the fieldwork to recombine evidence and to draw empirical conclusions. Following Yin (2009)'s guide to analysing case study evidence, an analytic strategy has been developed to provide the structure for evaluating the information collected. After implementation of this established strategy, prescribed analytic techniques will be further utilised to study outputs of the evidence to determine meaningful patterns, code frequency and code combinations. The logical conclusions are validated and further deliberated to establish meaningful contributions according to the research questions.

Chapter Outcomes:

- Conduct experimental procedure to gather data
- Deliberate analytic strategy
- Utilise analytic techniques to develop logical conclusions
- Validate results

5.1 Chapter Introduction

According to the case study research method in Chapter 4, this chapter covers the fieldwork for gathering data as well as the analysis of evidence collected. The process of analysing case study evidence is conducted in two parts, firstly defining the analytic strategy according to the case study analysis and secondly considering the five analytic techniques defined by Yin (2009), to explore the rationality of conclusions presented. Within this chapter the use of Computer Assisted Qualitative Data Analysis Software (CAQDAS) is also considered, where the need arises to interpret evidence into pockets of meaningful information, specifically combined to empirically substantiate conclusions made. This chapter concludes with the provision of the required information to present a final framework to be used for implementation.

5.2 Implementation Methodology

Regarding the implementation of a chosen research methodology, the following five sequential focus areas are highlighted by Cresswell (2009) involving; the method of inquiry, the research design process, the identification of participants, the data collection and finally the analysis and interpretation of data collected. Having established the method of inquiry as a case study analysis, the research methodology was discussed in section 4.2.4. The remaining implementation methodology will be further addressed in the following subsections.

5.2.1 The Case Study Process

Having selected the case study approach (section 4.2.4) as an appropriate approach for conducting this research, the implementation process begins with identifying the type of case as well as the information applicable to that case (Yin, 2009). Furthermore, utilising the framework as provided by Yin (2009), the evidence applicable to the case study research method should originate from multiple sources to enhance the reliability of the study. Bryman and Bell (2014) also refer to the necessity of keeping a comprehensive database of the data sources to facilitate the data analysis process.

Yin (2009) goes on to discuss the effectiveness of multiple sources of information within a case study database as providing the ability of forming a "*chain of evidence linking your research questions to your research protocol to the case study database to citations of specific evidence in your analysis and finally your report.*" Building on these concepts, multiple sources of information are established through the participant identification process, discussed in section 5.2.2. The information gathered is such that various sources within the

MC group are utilised, which in conjunction with the structured questionnaire, will be utilised to facilitate the gathering as well as analysis of information.

Bryman and Bell (2014) indicate that although there are specific approaches to the case study analysis methodology, it is also appropriate to make use of other general analysis techniques such as analytic induction, grounded theory or thematic analysis. Therefore within the structured questionnaire, analytic techniques such as thematic analysis will be further discussed in section 5.4. Yin (2009) proposes two types of analytic approach, namely the explanatory and the exploratory approaches. These two approaches are further explicated in Bryman and Bell (2014) as a subjective 'exploratory' and objective 'explanatory' approach.

These two approaches are dictated to where the focus areas of the researcher lies, to either investigate the clear questions and models based on literature in an objective manner or rely on subjective interpretations of reality from a participant. Therefore the analysis of this case study rests on an objective approach which according to Bryman and Bell (2014) is "*developing a description of the case which will form the basis for the research questions and an analytical framework to emerge inductively to organise the case*". Furthermore, considering the lack of literature for SAM, as established in Chapter 2, the case study approach concerning this study inherently incorporates the subjective feedback from participants where input from each participant is a key component to understanding the approach of this case study research, and where collective insight forms the basis of furthering the case study process.

5.2.2 Participant Identification

According to Cresswell (2009), qualitative participants are identified as purposeful samples rather than using a random sampling process as these individuals are selected based on their merit. This includes the participants' ability to best assist the researcher concerning the research problem, where the participants best hold the knowledge applicable to the research topic. This also allows the research to be more direct and pragmatic. In order to holistically consider the research problem, the goal of sampling is to include those persons within their environments and the specific concepts which will provide the most insightful understanding towards gathering the required information. Certain boundaries and parameters need to be set in order to focus the sampling process and ultimately contribute toward the feedback received.

Considering the case study methodology as discussed by Yin (2009), to investigate a specific case study the sample of participants needs to be relevant

and related to the case study being investigated. Therefore technical managers within a private healthcare group are the basis for selection. There are 52 hospitals within the Southern African group, each with a head of the technical department, where, depending on the size of the hospital this position is held by a technical supervisor or a technical manager. Assisting these hospitals on a regional level are five regional managers, four technical specialists and two senior managers in the corporate division of the organisation. Within the qualitative exploratory approach, two sets of samples are identified. A homogeneous group of hospital technical managers as well as a secondary heterogeneous group involving participants assisting hospitals from within the corporate office environment, either as technical specialists or regional or senior managers.

The choice of initial samples within this study is based on representation within this private healthcare group as well as individual consent on the part of the technical manager representing various geographically separate hospitals. Initially the senior manager for this private healthcare group, was approached for approval of the homogeneous participant sample. He identified that a maximum number of ten hospitals (n=10) could be approached yet did not specify which hospitals could be selected. After considering the hospitals in terms of their size (based on patient bed capacity and number of theatres) as well as geographical location, ten hospitals were identified where initial contact was also made to confirm willingness to participate.

Once the initial development of theory was established amongst the homogeneous group of technical managers, the secondary process of selecting the heterogeneous sample was limited to the corporate division representing group management. The rationale for including the heterogeneous group within the study was to provide verification which offers feedback through gaining consensus regarding the research problem, research approach as well as the proposed framework for SAM implementation. Furthermore a solution was presented to the heterogeneous group to confirm validity of the concept. Regarding the proficiency of this heterogeneous group, this group currently offers guidance and leadership regarding strategic implementation and this was therefore deemed suitable for verifying the strategic implementation proposed by this research study. To approach this group, the same senior manager as before was approached where he agreed that the sample included corporate assistance, namely two regional managers and his input as senior manager (n=3).

5.2.3 Data Collection

Considering an active approach to collecting qualitative data within case study research, Yin (2009) proposed six common sources for collecting evidence; Doc-

umentation, Archival Records, Interviews, Direct observations, Participant-observation and Physical artifices. These six sources each have their own strengths and weaknesses as discussed by Yin (2009), where no one source has complete advantage over the other. Yin (2009) also confirms that these sources are highly complementary of each other and using multiple sources in fact strengthens the evidence presented in the analysis of the data. By utilising the multiple sources, Yin (2009) also describes the development of *converging lines of inquiry* which relates to a process of triangulation and corroboration of the information presented.

This concept of data triangulation also assists in clarifying issues related to construct validity due to the evidence being observed form various viewpoints in the research. Yin (2009) also discusses the prerequisites for multiple sources of evidence as being heavily burdensome on the researcher, who needs to master the various techniques of analysis for each source being utilised as well as the time-consuming nature of collecting data from various sources. Yet these prerequisites are easily justified due the many advantages which are presented when utilising multiple sources of evidence.

Investigating these six sources, the nature of this study is orientated in an operational service environment where various people's views can add insightful information regarding perceived inferences and explanations pertaining to the proposed research question. Furthermore archival records are also available in the form of a Computerised Maintenance Management System (CMMS), where this information is available to the researcher. Considering the strengths and weaknesses of the six sources as proposed by Yin (2009), the natural choices for the sources of evidence are interviews and the analysis of archival records. Using these two sources in conjunction allows the researcher to compensate the weakness of each approach with the strengths of the subsequent approach.

Interviews are targeted to focus directly on the topic of the case study, where perceived information can be gathered from multiple sources to triangulate common consensus. However, this approach to gathering evidence can also be considered biased due to the questions articulated within the interview, and the coverage of the information is limited to the experience of the interviewee. The collection of this evidence may also be inaccurate due to human nature, where evidence may be influenced by various factors which cannot be defined or controlled. Yet these identified weaknesses can be offset by comparing the evidence presented to archival records. These records can be considered information which is exact, unobtrusive and stable. This form of evidence also has a broad coverage, spanning a larger time frame, beyond that of various interviewees. Although the interpretation of the information may be biased toward the influence of the reporter, the priority of the information under

investigation is set forth by the interview and the researcher is therefore a third party to identifying the subject being reported.

Using an interview as the primary source for collecting evidence, this method allows the researcher to guide and focus the investigation with respect to the research problem. Yin (2009) identifies three types of interviews appropriate to a case study research design, namely an in-depth interview, a focused interview and lastly a formal survey. A structured interview between participants is identified as an appropriate data collection method, where this method forms part of the third interview method type, namely the formal survey. This method of collecting evidence is selected due the variety of participants that were chosen throughout southern Africa, representing a diverse group of technical managers within a single organisation. Therefore considering that the interviewees were in the same technical position representing different hospitals, their experiences of the research problem are addressed in a uniform structured interview process.

This interview method is in the form of an electronic questionnaire communication, where participants are prompted to answer a series of predetermined questions. This allows the analysis and interpretation of the collected evidence to be evaluated in a standard manner where the format of the interview is exactly the same for all respondents in the sample. The questionnaire is developed in a systematic way to firstly inform participants of the study as well as the research problem and then to electronically collect responses to specified questions relating to their personal experiences. The answers to these questions include both closed and open-ended answers where the analysis of this information is related to the single case study under investigation.

Bryman and Bell (2014) separate the terminology for a questionnaire and structured interview, where they confirm that both concepts exist in cohesion however are separated on the basis of administration of the interview. However Bryman and Bell (2014) also further specify the concept of e-research or online surveys as being both structured interviews and self-completion questionnaires. Furthermore Bryman and Bell (2014) use these concepts as an analytic process to explore various data criteria to be captured and they elaborate about the criteria applicable to both a structured interview and a self-completion or self-administered questionnaire.

In order to commence with the data capturing process the researcher gained clearance from the ethical committee of Stellenbosch University (refer to Appendix B.2 for the supporting documentation) , as well as permission from the organisation in which the research is conducted. Relying on a panel of experts, namely technical managers within the private healthcare industry to be the

primary source of information, the questionnaire focuses on their professional experiences regarding maintenance and operational aspects which are captured within the questionnaire, where the group results are further analysed to validate consensus. Within these questionnaires the experts offer insight into the critical aspects surrounding the facility of an operating theatre. To conclude the structured interview, validation in the form a secondary interview is established where regional mangers and technical specialists react on the surmised information collected to concur on the value contribution of establishing the SAM technique as a means to better manage these facilities. Thus, these experts are encouraged to revise opinions about the research to highlight aspects which add the most value. Therefore the group will converge towards a benchmark and finally, the process is stopped after achievement of consensus.

With the data collection process established, more details are provided in the succeeding section, elaborating the type and context of the archival records which will be utilised, as well as the interview protocol and pilot case study established to further conduct this research.

5.2.3.1 Archival Records

Archival records as discussed by Yin (2009), often take the form of computer files and records which in the this case study relates to the organisational CMMS. Within the CMMS a standard is implemented throughout all hospitals where asset breakdowns are reported through a notification system which is then converted to a work order for the relevant technical employee (technician, artisan, handyman or assistant) to be attended to. These work orders can be used to track specific asset failure, where each work order relates to one specific piece of equipment within the hospital. By using Mean Time Between Failures (MTBF), asset expenses and other quantifiable information concerning the breakdown of these critical assets, the CMMS contains relevant evidence contributing to the research study for the specific assets under investigation. This information is also centrally accessible for all hospitals within the group and can be used in conjunction with a case study analysis to support information gathered in the interview process.

Yin (2009) further advises that for archival records to be relevant in a case study analysis, the conditions under which the evidence was produced and its accuracy needs to be verified. It is also important to be aware of the fact that the evidence was not created for the purpose of this case study and should therefore be seen in the context in which it was collected. These conditions should be carefully appreciated when interpreting the usefulness and accuracy of these records. These concerns are further discussed within the analysis of the information in section 5.4.

5.2.3.2 Interview protocol

Although Bryman and Bell (2014) discussed the case for surveys and questionnaires as a separate method of data collection compared to an interview, Yin (2009) motivates questionnaires as a formal and structured interview process. Yin (2009) describes this process as following the survey sampling procedure and instrument utilisation, however, that the questionnaire differs from a survey when compared to the use within a case study environment due to its relation to other sources of evidence. Therefore both Yin (2009) and Cresswell (2009) found that a procedure for a structured interview is relevant to both interviews conducted with the homogeneous and heterogeneous group being investigated within this research.

Cresswell (2009) discusses the following interview protocol which is relevant to formalising an interview as a data collection method. This protocol discuses the factors which influence the processes observed for a structured interview to be conducted.

1. A heading (date, place, interviewer, interviewee).
2. Instructions for the interviewer to follow so that standard procedures are used from one interview to another
3. The questions (typically an introductory question at the beginning followed by 4-5 questions that are often the sub-questions in a qualitative research plan, followed by some concluding statement or a question, such as, "Who should I visit with to learn more about my questions?".
4. Probes for the 4-5 questions, to follow up and ask individuals to explain their ideas in more detail or to elaborate on what they have said.
5. Space between the questions to record responses.
6. A final thank-you statement to acknowledge the time the interviewee spent during the interview.

Bryman and Bell (2014) further discuss the following considerations whilst implementing a questionnaire, where the components considered were initially reflected within the pilot test and further exhibited in the final questionnaire. The basic concepts as discussed by Bryman and Bell (2014) are elaborated as follows, where the implementation is further discussed in the pilot test section.

Layout An attractive layout is likely to enhance response rate. It is recommended that the questionnaire appear as short as possible, as long questionnaires may deter respondents. The layout should not be cramped, as flow and spacing are important to ensure all questions are answered and not accidentally overlooked.

Clear presentation The information needs to be clearly presented to the respondent and answering questions needs to be made as easy as possible. The styles and format should also be consistent throughout the questionnaire where instructions, headings, questions and colours are selected to accustom the respondent to answering questions and also representing a professional look and feel.

Required responses Whilst creating the format of the questionnaire, it is critical that the researcher keep in mind the response to be captured from the respondent. Apart from the information to be captured, the responses need to be analysed in a uniform approach where questions presented in a Likert scale can be precoded to draw specific conclusions. However this method may limit the response of the respondent where misinterpretation of the question may lead to an inaccurate reply. The respondent should not be led in a question to provide a required answer but it is important that the question itself is clear avoiding the possibility of ambiguous answers.

Clear instructions It is imperative that clear concise information is presented to the respondent to fully enable the person to complete the questionnaire. Misinterpretation of the question or the type of response required may render the information collected unreliable. It is also important to take into account the possible alternative means of interpreting or answering the questions. For example with multiple choice questions, respondents may select multiple answers instead of an intended single response.

Keep questions and answers together The flow of the questionnaire should not confuse the respondent, especially when alternative texts or images need to be referred to. Questions and answers should be kept together to prevent the incorrect answer to a question. The questions should be clearly separated where double-barrelled questions, as well as long questions should be avoided.

Closed and open-ended questions Open questions refer to a response where the respondent can answer as they feel appropriate, whereas a close response has preselected alternatives administered by the researcher. The issues that arise between these types of responses refer to the probability of restricting and leading the respondent as well as the type of analysis possible from the captured response. Closed questions are more easily analysed but limit the respondent in adding their own opinion, compared to an open response which can be difficult to code yet captures the intended reply of the respondent. Further advantages and disadvantages of each approach are considered with respect to precoding and post-coding

the responses which need to be carefully balanced within the questionnaire to ensure a well-rounded source of evidence which can be verified with respect to other sources and validated within the research being conducted.

Types of questions Various types of questions are appropriate to capturing the intended information relevant to the research being conducted. These types of questions include; personal factual questions, factual questions about others, informant factual questions, questions about attitudes, questions about beliefs, questions about normative standards and values and questions about knowledge. These distinctions clarify what is required from the respondent and guard against the incorrect type of question regarding the format of the response required.

Finally it is also important to keep in mind the primary goal of the research questions, where the questions asked within the questionnaire need to contribute information to the research. A clear requirement of each question needs to be established confirming what is needed as well as how it is intended to be answered. The respondent also plays a vital role and needs to be carefully selected, having appropriate knowledge of the content of the questionnaire and the ability to answer the questionnaire satisfactorily.

5.2.3.3 Pilot Test – Homogeneous Questionnaire

With regard to the interview protocol as set forth by Cresswell (2009) and the questionnaire factors prescribed by Bryman and Bell (2014), a structured interview is created as an initial questionnaire, set forth as a pilot test, conducted by a single respondent. This respondent is selected due to their close proximity to the researcher and the respondent could therefore provide feedback regarding the completion experience of the questionnaire. The initial questionnaire is provided in Appendix A.1.

Apart from the initial contact made by the general manager of technical operations, the questionnaire was designed to send out per email with a link to an online survey which included various sections, paged through by the respondent. These sections captured required information including the date and time of survey completion, respondents' details, an introductory preamble, consent to complete the questionnaire, questions related to the research question and finally a courteous thank you to conclude the questionnaire. The set of questions as illustrated in Appendix A, demonstrates both a mixture of open and closed-ended questions where if a closed-ended question was asked, the respondent would be further probed to discuss a general opinion of the closed-ended response. Furthermore the close ended multiple choice questions and the questions phrased as per the Likert scale method were administered

so as to restrict respondents from answering multiple selections, where an error message would assist with further support. The pilot test proved to be a success as the initial respondent's comments verified the intended information to be captured and also provided approval for the structure, layout and flow of the questionnaire being acceptable to the respondent. The initial questionnaire was therefore verified as the final version to be sent out to all homogeneous respondents and no additional alterations were required.

5.2.3.4 Pilot Test – Heterogeneous Interview

As identified in the research methodology in section 4.2.4, the proposed validation of the research is concerned with the verification of data collected by utilising a secondary interview process. The heterogeneous interview process involves a smaller sample group compared with that of the homogeneous group, where the interview process allows for feedback during the interview. Therefore the initial interview is considered to be the pilot test study which is conducted with the technical operations manager, to also obtain further participant approval.

This interview process is also a structured interview where a predetermined set of questions is formulated to extract required information uniformly between each participant. Furthermore a preamble document is created to provide the heterogeneous group pre-reading material which is required before the interview is conducted. Within this preamble, information is provided to each heterogeneous participant concerning the process of the study, the methodology as well as feedback concerning the interview process. This feedback will be further discussed in section 5.4, while the preamble is included in Appendix A.2

5.2.4 Data Analysis and Interpretation

Cresswell (2009) describes the data analysis and interpretation step as a means which *"involves preparing the data for analysis, conducting different analyses, moving deeper and deeper into understanding the data (some qualitative researchers like to think of this as peeling back the layers of an onion), representing the data, and making an interpretation of the larger meaning of the data"*. This analysis of evidence, as well as the interpretation thereof needs to be addressed in a structured manner to constructively process the information collected reliably as well as deriving meaningful contributions to a specific research objective. Therefore the process of data analysis needs to have a specific strategy, where various prescribed techniques can then be used within this strategy to interpret the information collected.

The approach by Yin (2009) to analysing the data within a case study analysis, discusses five techniques namely; Pattern Matching, Explanation building, Time-series Analysis, Logic Models and Cross-Case Synthesis. Building on the interpretive process as discussed by Cresswell (2009), the explanation building analytic technique as well as the pattern matching case study analytic technique, are utilised as the chosen analysis and interpretation methods. These two concepts differ due to complexity, however they complement the value derived through sequential analysis. Explanation building sets out to achieve analysis through building an explanation of the case in a narrative format. An original purpose is established as the basis of the explanation, where this technique uses an iterative progression to build a set of ideas which are refined through analysis of the data sets. This approach to gradual building of an explanation allows the researcher to entertain other plausible or rival explanations, yet remains focused on the original purpose established. This original purpose appropriate to the research study is set out in the following concepts, which highlight a certain theme set out to be proven by the evidence collected:

- Departments with highest maintenance priority
- Department with greatest economic opportunity
- Assets which are critical to operation of department
- Monitoring of failure instances
- Proactive or reactive asset support

Addressing these concepts, which are used as the basis for an explanation-building analysis, the evidence collected is then further subjected to a pattern matching technique (similar in concept to the thematic analysis addressed in section 5.3) used to compare this established foundation to validate initial concepts created by the researcher. Furthermore the information is analysed iteratively to expose alternative insights applicable to the research.

Bryman and Bell (2014) and Yin (2009) describe various strategic approaches for analysing data collection as well as being able to interpret the data meaningfully, which is appropriate for this case study research. These two approaches are addressed within the following section 5.3. Furthermore these strategic approaches coincide in concept with Cresswell (2009) where the approach discussed by Yin (2009) specifies the data analysis specifically for a case study approach which is further implemented in section 5.4.

5.3 Analytic Strategy

Yin (2009) emphasises the need to develop an analytic strategy before analysis can begin, as it defines how the research embraces the evidence to empirically satisfy the research questions. Bryman and Bell (2014) define three general strategies namely, *Analytic induction*, *Grounded theory* and *Thematic analysis*. Considering these strategies, thematic analysis is deemed the most appropriate towards guiding this specific research strategy, as unlike the other two strategies, this processes is a flexible method not tied to specific philosophical orientation. Thematic analysis is concerned with the informed judgement of the research to determine the relative weighting of processed evidence. The meaning and reference to the research question receives precedence as opposed to prevalence of a theme in the data collected. Therefore using the thematic analysis as a deductive strategy to conduct research, this top-down approach is guided by the researcher's theoretical framework. Bryman and Bell (2014) also further define a six-step approach to conducting a thematic analysis, as is discussed in section 5.4.

Considering Yin (2009)'s approach to case study data analysis, he goes on to discus four specific strategies used for the analyses of case study evidence. Utilising one or more of these strategies will assist the researcher in treating evidence fairly, produce compelling analytic conclusions and also prevent alternative interpretations which may be misunderstood or incorrectly interpreted. These four strategies include; relying on theoretical propositions, developing a case description, using both qualitative and quantitative data and examining rival explanations. Each of these strategies is considered below.

Relying on theoretical proposition The first strategy stems from the idea that the researcher follows theoretical propositions that led to the creation of the original case study. Hence theoretical orientation is used to guide the analysis of information where the proposition helps to focus the attention on certain data and ignore other data. The researcher's propositions would have helped to shape the data collection plan and therefore give priority to the relevant analytic strategies.

Developing a case description The second strategy requires a descriptive framework for organising the case study. This strategy involves the collection of data relevant to each topic within the framework, where the data collection instruments are designed before this framework has been established.

Using both qualitative and quantitative data The third strategy involves using both qualitative and quantitative data which has the greatest benefit as used in conjunction to a validation process, verifying data collected in

various qualitative and quantitative data sources. This process reveals a strong analytic strategy as the quantitative data is relevant to test the behaviour or events that the case study is trying to explain where an embedded unit of analysis is established within the broader case study. This allows the qualitative data to be used as a critical tool in testing the case study's key propositions within the defined environment. This strategy allows the researcher to develop a case based in quantifiable research and take this proposition further with the analysis of qualitative internal responses.

Examining rival explanations The fourth and final strategy is used to define and test rival theories concerning the topic being investigated. The researcher using this method allows the rival case study to become the driving factor for the case being investigated. This allows the researcher to challenge preconceived theories and provide evidence to disprove and hence endorse alternative case study analysis.

The four strategies defined by Yin (2009) are used in varying degrees to assist in the analysis of the information collected within this research. The researcher chooses to specifically embrace the reliance on theoretical propositions, which established the initial aims for the analysis guiding the findings with respect to addressing the research questions. Furthermore the use of both quantifiable (to a very small extent - in comparing archival records) as well as the qualitative interview evidence, the analyses strategy is further elaborated in section 5.4.

5.4 Analytic Techniques

The research methodology as set forth in section 4.2.4 as well as the research strategy discussed in section 5.3 describes a deductive thematic analysis involving a top-down approach, where patterns and themes formed within the evidence are judged by the informed researcher. Braun and Clark (2006) discuss a six-phase process of thematic analysis, where Bryman and Bell (2014) uses this process to further relate to specific case study analyses providing an interpretive process which can be followed as an analytic technique. Subsections 5.4.1 - 5.4.6 implement this procedure to analyse evidence collected within this research study.

5.4.1 Data Familiarisation

After having defined the methodology in Chapter 4 as well as the protocol to be used in the initial interview in section 5.2.3.2, the structure being used to address questions within the initial data gathering process is interpreted within this section. The original questionnaire is subdivided into various categories used to extract specific information. Breaking down the structure of

the questionnaire, eight categories have been identified which will be discussed separately, where the full questionnaire is available in Appendix A.1.

Consent The first part of the questionnaire introduces the respondent to the study, providing details of the ethical clearance as well as the aim of the study with respect the completion of the researchers studies. The consent of each participant is also mandatory before being able to continue with the research, where ethical protocol was followed as prescribed by the University of Stellenbosch.

Participant Details This includes name and contact details for each participant, as well as their personal learning experiences, areas of expertise and the number of years' experience within Mediclinic. This information is used to ensure that each participant completed the questionnaire once, as well as provide accountability to responses. By questioning the number of years' experience within the current position also confirms the suitability of the candidate, with respect to their knowledge of the hospital environment and general practices.

Hospital Details Specific details regarding the general hospital infrastructure is captured here. These details include; the total number of hospital beds [1], number of operating theatres, number of beds available in the ICU and the number of beds available in the emergency centre.

Introduction in AM From the researcher's personal experience within the MC group, it is apparent that the term asset management has a financial connotation due to the responsibility of the financial department in ensuring that assets are correctly represented on the CMMS, namely SAP. MC hospitals have an Asset Responsible Person (ARP) who ensures that the financial values associated with assets are upheld, as discussed in section 2.2.1. The technical department, commonly referred to within MC as the maintenance department, is for the purpose of the study responsible for PAM. The concept of PAM as well as the concept of SAM therefore needed to be introduced to the participant within the research group to ensure a correct understanding of the research objectives. The participants' understanding and interpretation of the concept also probed to ascertain whether the provided information is understood.

[1] The number of hospital beds refers to the total number of patients the hospital can accommodate at any given time period and is also used as a benchmark to measure the general size of the hospital. The hospital occupation is also measured according to the number of beds booked on a monthly basis, referred to as a "*patient per bed day*" representing an occupation percentage which is used to report infrastructure Key Performance Indicators (KPIs) such as water, power and medical gas usage. For example figures such as litres per bed day, Kilowatt Hours (KWh) per bed day are reported on a monthly basis.

Critical Asset Systems Having established the fundamentals of PAM as well as some of the documented best practices regarding the scope of managing physical assets, the participant was introduced into a general discussion regarding the critical facets surrounding asset systems within various departments in the hospital environment. The critical nature of the asset system was regarded in terms of a maintenance priority as well as in terms of a economic revenue priority. From these asset systems specific assets were also identified.

Asset Malfunction Once the assets systems and the specific asset were identified, the malfunction of these assets was further investigated. The effectiveness of the reporting systems within the hospital is also investigated to determine the general procedure for reporting the failure of asset systems as well as the record of the details regarding failure.

Operating Theatre Assets The operating theatre is a specific focus of this study, therefore it is addressed separately within the questionnaire to establish certain details regarding the assets which support the infrastructure of a theatre complex. From the researcher's personal involvement with these critical assets a preliminary list was created where the respondent is required to rate the most important asset. The respondent is also required to provide additional information regarding other critical assets which were not included in the list. Further to establishing the most important assets, circumstances regarding asset failure leading to unavailability of the theatre is discussed, where instances of such scenarios are probed from the respondent. The reporting of these failures is also investigated to determine whether any specific record is held of theatre unavailability.

Monitoring of Asset Infrastructure The final component of the questionnaire is regarding the administration of these identified critical assets to establish whether these assets are being monitored proactively or reactively to failure. The systems identified to monitor these assets are also discussed to determine how they are utilised in the management of these critical systems, where the questionnaire further probes regarding the value contribution of using a smart monitoring system.

5.4.2 Initial Codes Generated

The codes generated from the questionnaire represent an awareness of the content, which is presented to the reader so as to summarise the important aspects of the data collected which contributes value to the research study. This allows the researcher to present evidence contributing to the broader analytic themes of the research where codes are not merely derived from specific words contributed by the respondent but rather concepts specific to certain themes.

The codes created below consist of phrases extracted from the compilation of feedback given by the respondents where this information is consecutively grouped into phrases, not yet analysed.

The use of a CAQDAS could be utilised to further assist the researcher with respect to qualitative analysis of the questionnaire feedback, where generated codes can be captured electronically and analysed through software to further achieve themes as prescribed within this thematic analysis. However CAQDAS is not utilised within this research, where it was determined as not required due to the relatively small amount of qualitative data which is analysed. The researcher chose to complete the analysis utilising a prescribed manual thematic analytic approach.

The subsections defined in section 5.4.1 and section 5.4.2, are further elaborated to describe the responses from each of the ten participants, where a summary of their responses to the questions are captured in numerical sequence below. Furthermore the initial sections containing confidential information are omitted.

Introduction in AM

1. AM is means to operate and maintain assets efficiently and cost effectively as well as provide advice to replace critical assets.
2. Assets are items which provide value to the services offered by the company, where standards are enforced by an AM policy. The condition of assets should be monitored according to these standards.
3. The management of assets includes procurement, tracking, maintenance and decommissioning.
4. Assets can be seen in a financial sense to record organisational wealth, exercise control, gather information and keep record of maintenance. Historic data can be used to make informed decisions.
5. AM is a mechanism to oversee procurement, risk management and maintenance of all assets.
6. The assembly of information concerning each asset, where the life cycle of each asset is important.
7. AM involves a strategy concerning asset maintenance and replacement.
8. *No participant response*
9. Key to asset management is the asset register, accumulating asset information allowing correct identification.

10. Asset life cycle management through maintenance records assists with decision-making and risk management.

Critical Asset Systems

1. Areas where equipment failure can have an immediate catastrophic effect are rated highest, such as theatres and ICUs. Criticality of an asset system also needs to be considered from a strategic point of view.

2. Need to consider nature of hospital, availability of external services. Where theatre is most important

3. Consider the interlinked nature of asset system throughout the hospital, where the system failure is applicable to all departments

4. Theatre is the highest priority due to patient risk during operation as well as ICU

5. Patients and doctors are dependent on effectiveness of critical asset systems.

6. Physical infrastructure is the most important supporting all assets such as life-supporting assets.

7. Asset systems which support the most critical patients, where patients are the most at risk.

8. *No participant response*

9. Customer service compared to patient life support. Although other areas are operationally important, patient safety is the most critical.

10. Life support equipment is the most critical to patient safety, where theatre utilises the most life-support equipment.

Asset Malfunction

1. In cases of critical failure in theatre, most notifications of malfunction are reactive, where communication is received from users. Breakdown also not always logged on CMMS.

2. Critical notifications in the form of phone calls, where breakdown not always logged on CMMS.

3. Equipment which has alarms or systems with audible notifications are reported by the end user.

4. Critical equipment has alarms monitored by personnel. These are telephonically reported, breakdown incidents are submitted on CMMS afterwards.

5. Alarms from equipment are reported by end users.

6. Reliance on work orders to monitor historic asset malfunctions on life support equipment raised by end users.

7. Critical asset malfunctions are monitored through SCADA monitoring system where technical manager and standby technician are notified via email and technical team can monitor asset failure on a visual display in workshop.

8. Reliance on CMMS to follow MC procedures

9. Telephonic calls from end user are accepted to alert only critical malfunctions, where breakdown incidents are mostly logged after the event occurred.

10. Reliance on CMMS to attend to breakdown and preventive maintenance.

Operating Theatre Assets

Specific assets have been identified as crucial to theatre operation. Feedback regarding these specific assets from each respondent will be captured in section 5.4.6. The feedback below refers to the importance of the theatre as well as the assets associated with supporting the theatre infrastructure.

1. As a rule of thumb the area and also the assets utilised with the highest patient risk are also high revenue items with the greatest priority. Systems such as the medical gases, electrical and climate control have the highest priority to supporting a theatre.

2. Without a theatre complex and ICU a private hospital would not be able to survive economically. Electrical reticulation is the most important.

3. Theatre and ICU are the highest generators of income. Electrical reticulation failure can cause theatre unavailability.

4. Highest income generated is from theatres and ICUs. Electrical reticulation, medical gases, operating lights and climate control are crucial to theatre operation.

5. Operating theatres are the economic hub of the hospital, the more operations performed the higher the income generated. ICUs generate a high income per patient however patient turnover is less compared to theatres. Emergency water supply is crucial.

6. Every department influences the operational aspect of a hospital. Electrical reticulation, medical gases, climate control and operating lights.

7. Theatre and ICUs are considered high income generators. Electrical reticulation is important to theatre uptime.

8. *No participant response*

9. Operating theatres are the main income generating department where various supporting departments are required to ensure operational effectiveness. Natural disasters can affect theatre downtime, where equipment breakdown in such a situation is not preventable.

10. Theatre is a high revenue generator, however the non-revenue generators are also important, rendering services to the income generators. Climate control in theatre also ensures sterility and is crucial to theatre operation.

Monitoring of Asset Infrastructure

1. SCADA required to electronically monitor critical assets. Strategic checks are conducted daily for a visual inspection and to manually collect information from asset infrastructure.

2. Daily walkabout with visual inspection on critical asset infrastructure. SCADA is a proactive means to monitor critical assets

3. Alarms are monitored for reactive asset failure, where some alarms are proactive such as water or medical gas pressure failure. Strategic checks are conducted daily by qualified persons.

4. Currently manual check list conducted daily for critical equipment, which is filed for future reference. Implementation of SCADA to allow quicker response times.

5. Perform daily strategic checks where discrepancies are reported and attended to. Monitoring system can add value to assist in AM.

6. Daily manual records kept concerning critical assets. CMMS also utilised to reflect on historic asset failures, where action plans are created to attend to issues.

7. Alarms in place which reflect on failure of certain infrastructure elements, such as medical gas and water supply. Also certain measuring points established daily to create an alert if these are out of limits. Electronic monitoring can allow more informed decisions to be made.

8. Utilise MC maintenance procedures to monitor assets. Electronic monitoring has proven to add value in performance of assets.

9. Proactive planned maintenance according to CMMS. Electronic monitoring to be used in conjunction with manual monitoring.

10. Utilise planned schedules and information from CMMS to reflect critical assets. Electronic monitoring allows better record-keeping of asset information.

5.4.3 Theme categorisation

This step involves searching for themes within the data collected and reported in section 5.4.2, where the identified codes in the previous step can each be further captured within a basic theme. By conducting this theme categorisation, relevant data can be gathered or grouped together which pertain to the same potential theme.

As with the previous section, section 5.4.1 will again be used as a framework, where the same sections will be omitted as section 5.4.2.

Introduction in AM

- Encompassing processes to managing assets
- A means of maintenance record-keeping
- Assist with asset decision-making abilities
- Recording and grouping identification aspects of asset
- Asset risk management
- Recording asset information for replacement strategies
- Tracking and storing asset details

Critical Asset Systems

- Equipment failure leading to catastrophe
- Life-supporting equipment
- Central nature of asset infrastructure
- Patient risk
- Operational services compared to patient safety

Asset Malfunction

- User feedback
- Notifications are reactive
- Not reported on CMMS
- Audible alarms for user notification
- SCADA monitoring as a solution
- CMMS reliance to capture malfunction details

Operating Theatre Assets

- High patient risk relates to most important asset
- Theatre and ICU assets most important
- Theatre is economic hub of hospital
- Theatre highest income generator
- Theatre unavailability not measured

Monitoring of Asset Infrastructure

- Strategic visual inspections of critical assets
- Proactive monitoring capabilities
- Electronic monitoring
- CMMS for historic record keeping
- More informed decisions for identified measuring points
- Manual methods to be used in conjunction to electronic monitoring
- Record-keeping of asset information

5.4.4 Association and pattern recognition theme review

The previous step, theme categorisation, involves creating a basic theme from the generated codes whereas this step furthers the process in reviewing the newly created basic themes. This step involves confirming whether the extracted codes and basic themes of the data set can be grouped under an organised consolidated theme. Therefore this third level of sorting, pertains to organising the themes, thereby confirming the extracts from level 1 and the entire data set of level 2, can be used to generate a thematic map of analysis.

Compared to the previous section, the framework established in section 5.4.1, are not be used for organising themes in this section. Instead, the consolidated themes established are relevant across the entire research feedback. The same sections will be omitted as section 5.4.3.

1. Life cycle approach to managing assets
2. Asset risk management
3. Criticality of life support equipment
4. Reactive feedback to asset malfunction
5. Important asset infrastructure - Asset systems in theatre
6. Theatre unavailability
7. Electronic data acquisition

5.4.5 Interpretation and representation of themes

Once the codes, basic themes and organising themes have been established, by means of ongoing analysis this step involves refining the specifics of each theme and the overall story the analysis tells. Hence a representation is generated which establishes clear definitions and names for each theme. This is captured within Table 5.1 below.

This table is used in conjunction with the feedback provided in section 5.4.6, to further elaborate on the feedback in context to this research study.

Table 5.1: Thematic Map of Technical Manager Interview Feedback

Codes	Basic Themes	Consolidated Themes
Introduction in AM	Encompassing process managing assets	AM Life cycle approach
	A means of maintenance record-keeping	
	Assist with asset decision-making abilities	
	Recording and grouping identification aspects of asset	
	Asset risk management	Asset risk management
	Recording asset information for replacement strategies	
	Tracking and storing asset details	
Critical Asset Systems	Equipment failure leading to catastrophe	Criticality of life-support equipment
	Life-supporting equipment	
	Central nature of asset infrastructure	
	Patient risk	
	Operational services compared to patient safety	
Asset Malfunction	User feedback	Reactive feedback
	Notifications are reactive	
	Not reported on CMMS	
	Audible alarms for user notification	
	SCADA monitoring as a solution	
	CMMS reliance to capture malfunction details	
Operating Theatre Assets	High patient risk relates to most important asset	NB infrastructure - asset systems in theatre
	Theatre and ICU assets most important	
	Theatre is economic hub of hospital	
	Theatre highest income generator	
	Theatre unavailability not measured	Theatre unavailability
Monitoring of Asset	Strategic visual inspections	Electronic data acquisition
	Proactive monitoring capabilities	
	Electronic monitoring	
	CMMS for historic record-keeping	
	More informed decisions for identified measuring points	
	Manual methods to be used in conjunction to electronic monitoring	
	Record-keeping of asset information	

5.4.6 Explanation and abstraction

The final step of the analysis procedure affords the opportunity for analysis of the grouped data. This process involves selecting vivid, compelling extract examples which demonstrate the most appropriate feedback toward addressing the research question and literature. This final step is a report of the steps used in analysis, which can be used to summarise the data analysis process.

5.4.6.1 Life cycle approach to managing assets

From the responses recorded, a reliance on the CMMS is highlighted as a critical tool to managing the life cycle of assets. Information captured within the CMMS is used to make decisions concerning the procurement, maintenance and replacement interval of certain assets. Regarding the maintenance of critical assets, the utilised CMMS is used to output both preventative maintenance based on a time-based maintenance strategy, as well as breakdown notifications created from users within the hospital.

Preventive maintenance which is controlled by the CMMS is a reliable source of information, depending on the feedback collected on completion of the work order. Poor information can also be managed within the department to ensure correctness. However the quality of information received from breakdown is questionable due to the user. The end user is from another non-technical department, where information may be incorrectly recorded if recorded at all.

Various reports which are available from the CMMS, allow decisions to be made concerning the asset life cycle management. However these report are only as accurate as the information collected. The correctness of the information within the CMMS is questioned, which presents a strong case for collecting and specifically recording, asset information from the source, i.e. the asset itself.

5.4.6.2 Asset risk management

Asset risk management may be considered as part of the life cycle approach to managing assets, where the managing of risk is encompassed within the asset management strategy. However, due to the nature of assets within the hospital environment, where above-average risks are involved, the concept of risk management is an important factor considered by the responses from the homogeneous interview.

From the responses it is evident that risks are managed from reflection of breakdowns captured on CMMS, which are monitored over a monthly period. Furthermore instantaneous alarms connected to strategic assets, alert the end

users who report faults via telephone calls to the technical department to attend to immediately.

As with the previous subsection, the concept of the end user who is responsible to report incidents to the technical department, allows human error to contaminate results reported by the CMMS as well as reported faults. From the responses it is clear that certain scenarios exist where users do not correctly capture breakdowns, where personal experience from the researcher also indicates that certain circumstances exist where end users ignore alarms and do not report them. Due these findings, a further case is made to collect information directly from the asset to enhance value for monitoring the risk of critical assets.

5.4.6.3 Criticality of life-support equipment

Assets which are critical to the operation of the department are categorised within MC in terms of three priority applications. These priorities are classified with the following definitions; life support, strategic, and general. Life support is considered the most critical as it affects the patient's life directly, whereas strategic assets are those which can have an adverse effect on the operation of the business.

Regarding the responses from the homogeneous questionnaire directly, the highest priority life-support equipment includes the following;

> "Within the Mediclinic group, these assets have been identified and are classified as Category 1 items. It basically includes all life support assets/asset systems. It includes entire systems, like electrical reticulation, which is composed of all assets related to supplying normal or standby power to the hospital (generators, UPS's, switchgear etc.) or water reticulation, including emergency water supply. It can also be specific pieces of life support equipment, like ventilators or defibrillators." - Respondent 1

> "There are more than one answer. Physical infrastructure are according to me the most important critical." - Respondent 6

> "We categorise assets in three categories eg, life support, strategic and general. Life support is critical to ensure our main goal of patient safety during the stay. |Strategic equipment enables us to run the business and the rest not categorised as such is categorised as general. Theatre as a critical unit uses life support and strategic assets and is most probably the biggest cluster of high valued assets in any hospital with the biggest impact in the business. ICU second to that followed by the wards." - Respondent 10

Central assets systems such as the electrical reticulation, water reticulation (including emergency water), gas reticulation as well as climate control and sterilisation have been identified as some of the most critical infrastructure components. The components are central to the entire hospital where certain departments utilise more of these assets due to their support of patients' lives.

5.4.6.4 Reactive feedback for asset malfunction

Regarding notifications for critical asset malfunctions, nine of the ten respondents confirmed that feedback was directly received from the end user. In most cases an alarm notifies the end user, where the end user then utilises telephonic contact as the fastest means of reporting asset system malfunction to the technical department.

> "Only certain air handling units and autoclaves can be monitored, remotely, but they are not set up to generate alerts under certain conditions, so it add very little value. We are in the process of implementing SCADA, but that will mainly monitor plant equipment, not equipment used in theatre. Strategic checks are performed daily, but again, it only covers plant equipment and is only done once a day, 5 days a week. All critical equipment have maintenance schedules, but most are only serviced/checked once per year. Our current system is therefore currently mainly reactive." - Respondent 1

Although proactive planned maintenance checks are conducted according to a time-based schedule per asset, where daily visual inspections are conducted in the week, respondent 1 clarifies that immediate feedback is lacking where proactive notifications can be generated from an electronic monitoring system.

5.4.6.5 Important asset infrastructure – Asset systems in theatre

Within this research study, all life-support assets are not considered relevant to the study which is only concerned with assets affecting the support of infrastructure within specific departments of a hospital. The highest priority maintenance departments are indicated in Figure 5.1 below.

Figure 5.1 is a summary of the responses regarding a ranking of the most critical maintenance department within the hospital. It is evident form the responses that the operating theatre and ICU are the most critical, where 100% of respondents gave theatre the highest ranking. Therefore assets supporting the infrastructure of the theatre department have the highest maintenance priority and therefore consequently so to for monitoring purposes.

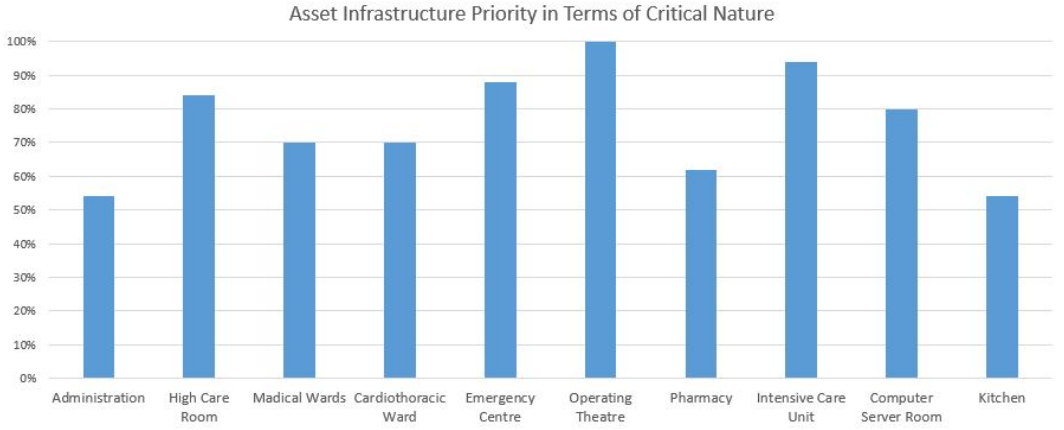


Figure 5.1: Interview Response for Departments with Critical Asset Infrastructures

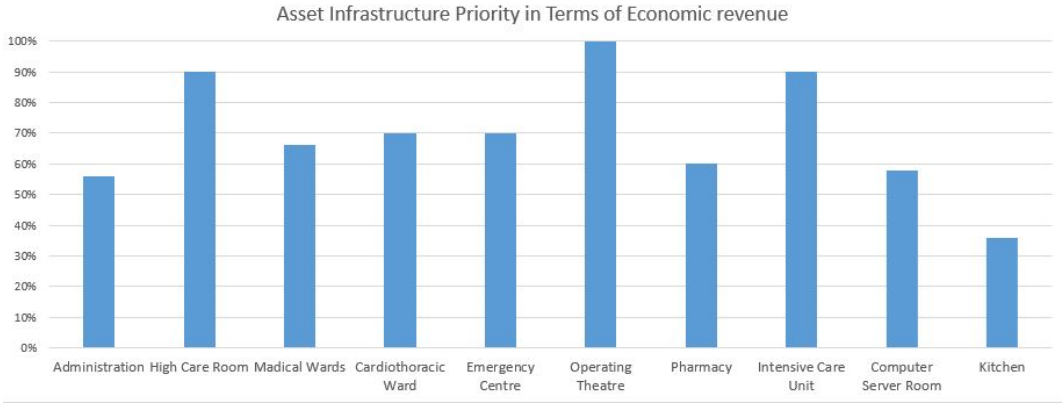


Figure 5.2: Interview Response for Departments Important for Economic Revenue

When rephrasing the question to confirm, in terms of economic strategy, which department is the most important, Figure 5.2 confirms the operating theatre as the highest priority. Therefore, in terms of both maintenance and strategic importance, the operating theatre is confirmed to be the most important.

5.4.6.6 Theatre unavailability

Having established the operating theatre as the most important in terms of maintenance priority and strategic importance, the infrastructure of assets within this department are to be considered as having the greatest importance. Figure 5.3 depicts the ranking of the most important assets where if any of these assets fail, the patient's life will be in danger and the theatre would be unavailable for use.

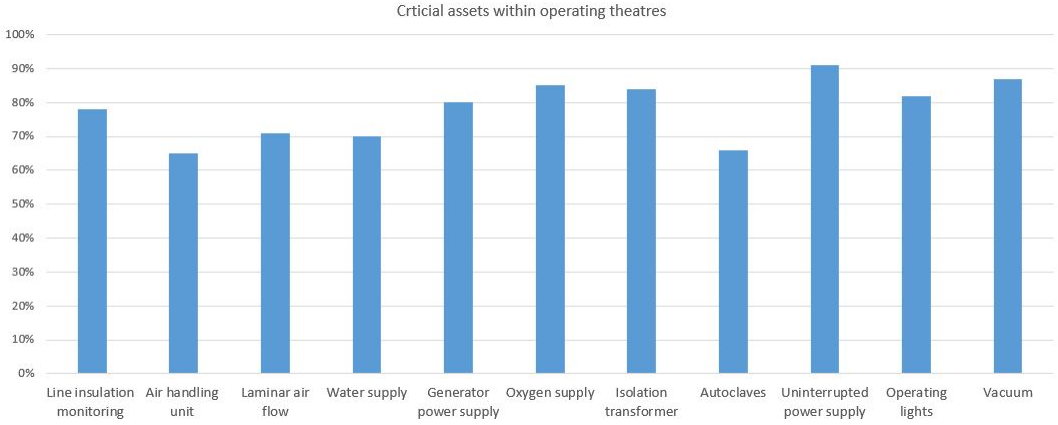


Figure 5.3: Interview Response for Critical Infrastructure Assets within an Operating Theatre

It is evident from Figure 5.3 that majority of these assets have high average rankings. Regarding the priority and the life-support classification of these assets, it is important that all assets be monitored where individually the importance of each asset has been confirmed by the respondents.

Furthermore, of the ten responses, seven technical managers reported that they are not keeping record's of theatre unavailability. Of the three responses which replied "yes", the method of record-keeping was in the form of a month-end report to corporate office or with respect to the CMMS. Confirming that these assets are critical in nature, both in terms of patient safety as well as business importance, various means should be utilised to gather appropriate information in order to mitigate risks as far as possible.

5.4.6.7 Electronic data acquisition

Strategic visual monitoring of assets is a MC standard policy where strategic assets are identified by each hospital. This check is conducted by qualified personnel (mostly artisans) and information is recorded on a checklist and manually filed for future reference. However the possibility arises that during a visual inspection certain aspects could be accidentally or even due to ignorance, overlooked. The information which is manually recorded, is also cumbersome to capture electronically where as a result analysis of information is not conducted on a continual basis due to lack of electronically captured information.

When respondents were asked the question *"Do you feel these monitoring systems can add value to your role within the asset management and managing asset availability within your hospital environment? "*, 100% of the respondents replied yes, where some of the responses included:

> "Yes it keeps you informed and you can take informed decisions when something happen" - Respondent 7
>
> "Yes. This will help to be proactive and to respond quicker than to wait for someone to phone." - Respondent 3
>
> "Yes, information from monitoring systems has proven valuable in improving plant performance." - Respondent 8
>
> "Yes, this can assist in limiting man hours spend on checks and record critical valuable information for decision making on risks and energy saving initiatives." - Respondent 10

From the responses presented it is evident that by utilising electronic monitoring devices, such as those identified within a SAM implementation plan, value can be derived through more information to make more informed decisions. This applies specifically within crucial areas such as the operating theatres where centrally located asset systems support the hospital infrastructure both in terms of strategic business importance but also in terms of patient life support.

In conclusion to the responses presented, a SAM policy solution is proposed to assist technical managers within the private healthcare sector to implement a SAM plan to monitor critical assets to mitigate potential asset failure.

5.5 Proposed Policy Framework

In order to address the concerns identified during the analysis of the homogeneous questionnaire and more so the analysis conducted in section 5.4, where a breakdown explanation and abstraction is conducted in section 5.4.6, the proposed implementation of SAM is considered a viable solution to electronically monitor critical infrastructure assets within this private healthcare group. Fundamental concepts addressed in section 3.5 and particularly section 3.5.5, regarding an ideal policy framework analysis, will be further utilised regarding a practical application.

In order to implement the concept of SAM within this corporate group, the first aspect would be to create a standard policy which addresses the implementation of SAM as approved by head office. To go about creating such a policy, within the hospital environment, the literature study as well as the feedback received from the initial responses of the homogeneous questionnaire are considered. Following the procedure outlined in section 3.5.4, this process is captured in a standard MC format policy document. The basis of this

document is established from the information value loop, where this concept is further modified to expand on the existing processes established within the implementation methodology. The modifications made to the original concept allow the document to be more applicable to existing implementation standards within the private healthcare group.

Figure 5.4: Proposed SAM Continuous Improvement Cycle

Figure 5.4 is a cyclical concept where a "planning" phase is included in the framework as the initial starting point, concluded by an actionable response. Specific information relevant to the application of this procedure is included in the outer circle of the process, detailing the hardware which has been standardised within the corporate group. This information offers a better understanding to the end user who will recognise these phrases and concepts within their own hospital.

Using Figure 5.4 as the basis of the document, each phase is expanded with recommendations on how to go about implementing the concept of SAM. The proposed document is available in Appendix D.1.

The policy document presented is self explanatory, with specific references to ensure that existing MC standards are adhered to where this policy document is a support implementation procedure specifically aimed at utilising electronic monitoring software, in the form of SCADA, to achieve actionable results. Concerning the business environment in which this document is presented,

the Return on Investment (ROI) is a key aspect to supporting the initial expenditure in obtaining the required hardware and software elaborated within the policy.

As elaborated within section 5.4.6 and specifically section 5.4.6.7, technical managers within the group realise the potential for the electronic monitoring requirements. However there is no existing guideline to support them with respect to an implementation procedure. The proposed policy procedure highlights critical assets as identified in section 5.4.6, where the feedback from these ten correspondents is utilised to concur on the most important implementation factors that need to be taken into consideration. Furthermore the validation of this document is further elaborated on in section 5.6.

5.6 Validation

Regarding the information outlined in section 4.3 describing the verification of the research conducted, this section further elaborates on the procedures implemented to obtain the results further utilised to develop the research findings and conclusions. This section focuses on two concepts utilised within the research methodology to strengthen the research framework. Firstly, with the data gathered within the initial data gathering process, the homogeneous interview is verified by utilising quantitative data retrieved from the organisation's CMMS. The second approach to improving the research validation is conducted through a face validation process used to confirm whether the research conducted is considered viable by the intended end users.

5.6.1 Data Verification

The data collection process discussed in section 5.2.3, elaborates on multiple sources of information to accomplish data triangulation as a means of data verification. Apart from the homogeneous interview conducted with technical managers, archival records and administrative data are also utilised to strengthen feedback and verify analysis.

5.6.1.1 Participant representation

The homogeneous group's personal experiences are further investigated to scrutinise qualifications related to the field of research being conducted, which is further used to validate their responses. A summary of the responses include the fact the average number of years experience within the group for each participant amounts to more than 8 years. Furthermore, the qualifications among the participants include experience within mechanical, electrical, clinical, manufacturing, leadership and management skills.

Table 5.2: Homogeneous participant experience

Years experience within current position	Participant Experience
4.5	Mechanical; Management / Leadership; Plant Manufacturing; Research and Design
3	Electrical; Electronic
6	Electrical; Electronic; Management / Leadership
8	Mechanical; Electrical; Electronic; Industrial; Management / Leadership
4	Mechanical; Management / Leadership
22	Mechanical; Electrical; Electronic; Industrial; Clinical; Management / Leadership; Construction; Plant Manufacturing; New technology
4	Mechanical; Electrical; Electronic; Clinical; Management / Leadership; Computer Science / ICT
6	Mechanical; Electrical; Electronic; Plant Manufacturing; Research and Design
14	Mechanical; Industrial; Management / Leadership; Construction; Plant Manufacturing
11	Clinical

These responses are therefore deemed more relevant to the research, due number of years experience, practical knowledge and qualifications relevant to the field of study.

5.6.1.2 Archival Records

Assets identified as critical from section 5.4.6.5, are selected and further investigated within two identified hospitals. The reason for choosing these two hospitals is due to the availability of the information from the CMMS to the researcher, as well as the researcher's personal involvement in working within these technical departments. These hospitals will not be named to preserve confidentiality, however they are confirmed as separate in terms of location and size, where one hospital was included in the homogeneous study and the other not. Information from the CMMS is extracted to highlight asset failures, whilst also looking at cases of asset failure and considering Mean Time Between Failure (MTBF). Furthermore administrative data concerning hospital occupancy and theatre utilisation are also extracted from these two specific

hospitals to further verify analysis from the homogeneous interview.

MTBF is a means of measuring the average operational time between failures. It is considered an indication of reliability where historic data can be used to highlight certain trends Campbell *et al.* (2011). MTBF is calculated by using the total available time (some of time between failures), divided by the total number of failures. Therefore a low MTBF value represents a negative operational history; where the asset has experienced more failures over a total time, or has a low operational time representing availability. It is important to note that the time between failures is measured from the time of operation after the previous failure of the asset, to the time of the next failure. All preventative maintenance work is excluded from the MTBF calculation, where only breakdowns are considered in the form of work orders created to repair the damaged equipment. MTBF is therefore calculated as follows:

tf = time of next failure
to = time of operation after previous failure
n = number of failures

$$MTBF(t) = \frac{\Sigma_0^x (tf_x - to_{x-1})}{n(t)} \tag{5.6.1}$$

As identified within the homogeneous research, an autoclave is considered to be a critical asset considering the infrastructure provided for an operating theatre. It is a device used to sterilise theatre instruments which are to be reused for further operations. This sterilising device has a certain capacity where instruments can packed within the autoclave which undergoes a superheated steaming process, using both water and electricity to complete a sterilisation cycle. The MTBF data illustrated in Figure 5.5 is for a single autoclave utilised in hospital 1.

Maint	Work center	Order	Order	Opr. short text	Description	Description2	Sort field	System Status	Act.finish d	Ref date	Priority	Failure days
1049	TWVGLTRN	4000022690	PM01	green-repair Autolave	CSSD 01	Autoclave, Steriliser,	0123309	CNF TECO	20/05/2016	17/05/2016	2 - Urgent Work	3
1049	TWVGLAR3	4000022690	PM01	green-repair Autolave	CSSD 01	Autoclave, Steriliser,	0123309	CNF TECO	20/05/2016	20/05/2016	2 - Urgent Work	
1049	TWVGLTRN	4000035246	PM01	Th1-4 autoclave (Ron) faulty.	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	11/08/2016	11/08/2016	2 - Urgent Work	0
1049	TWVGLAR3	4000049239	PM01		CSSD 01	Autoclave, Steriliser,	0123309	CNF TECO	30/09/2016	19/09/2016	2 - Urgent Work	
1049	TWVGLHM3	4000049239	PM01	Theatre 1-4 ccsd Ron autoclave faulty	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	30/09/2016	19/09/2016	2 - Urgent Work	11
1049	TWVGLTRN	4000066583	PM01	Jacket leaking on autoclave Ron.	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	31/10/2016	31/10/2016	2 - Urgent Work	0
1049	TWVGLTRN	4000083373	PM01	Autoclave Ron is faulty.	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	07/12/2016	05/12/2016	2 - Urgent Work	2
1049	TWVGLTRN	4000101674	PM01	Faulty autoclave "Ron"	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	12/01/2017	12/01/2017	2 - Urgent Work	0
1049	TWVGLHM1	4000076873	PM01	change extractor fan in autoclave room	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	15/03/2017	07/02/2017	2 - Urgent Work	
1049	TWVGLAR3	4000193174	PM01	Theatre 1-4 ccsd RON Autoclave stuck	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	15/05/2017	15/05/2017	2 - Urgent Work	0
1049	TWVGLAR3	4000193172	PM01	Theatre 1-4 ccsd RON faulty	CSSD 01	Autoclave, Steriliser,	0123309	CNF PRT TECO	16/05/2017	16/05/2017	2 - Urgent Work	0
											sum	16
						Total days			364		MTBF	44

Figure 5.5: Data Extracted from CMMS Revealing Autoclave 1 Failures for Hospital 1

From the data recorded over a 364 day period, three of the breakdowns recorded on CMMS have been omitted in the calculation and highlighted in red. The first two breakdowns represent duplicate work orders for multiple artisans conducting the work, where the third work order is concerning a request for a new fan which has not equated to asset unavailability. Within the calculation, the total days of unavailability (16) is subtracted from the total number of available days (364 days) and divided by the total number of failures (8 failures). Considering the resultant MTBF value of 44, this risk is offset by having two other autoclaves within hospital 1, where the MTBF values are calculated at 15 and 52 in Figure 5.6 and Figure 5.7.

Maint	Work center	Order	Order Type	Opr. short text	Descript	Description2	Sort field	Reference Date	Act.finish date	System Status	Priority	Failure days
1049	TWVGLAR1	4000025825	PM01	Faulty autoclave (Allie)	CSSD 01	Autoclave, Steriliser	0647962	22/06/2016	28/06/2016	CNF PRT TECO	2 - Urgent Work	6
1049	TWVGLAR1	4000137450	PM01	Investigate faulty pump that was replace	CSSD 01	Autoclave, Steriliser	0647962	02/03/2017	02/03/2017	CNF PRT TECO	2 - Urgent Work	
1049	TWVGLAR1	4000284096	PM01	Theatre 1-4 ccsd autoclave faulty	CSSD 01	Autoclave, Steriliser	0647962	18/07/2017	18/07/2017	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLAR3	4000120631	PM01	Theatre 1-4 Autoclave gasket loose	CSSD 01	Autoclave, Steriliser	0647962	10/02/2017	13/02/2017	CNF PRT TECO	2 - Urgent Work	3
1049	TWVGLAR3	4000131576	PM01	Autoclave Training and Installation of p	CSSD 01	Autoclave, Steriliser	0647962	21/02/2017	21/02/2017	CNF PRT TECO	1 - Planned Work	
1049	TWVGLAR3	4000135946	PM01	Repair pump on "Allie"	CSSD 01	Autoclave, Steriliser	0647962	28/02/2017	28/02/2017	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLAR3	4000137532	PM01	Theatre 1-4 autoclave faulty	CSSD 01	Autoclave, Steriliser	0647962	02/03/2017	03/03/2017	CNF PRT TECO	2 - Urgent Work	1
1049	TWVGLAR3	4000143760	PM01	Theatre 1-4 PLease repair autoclave	CSSD 01	Autoclave, Steriliser	0647962	08/03/2017	08/03/2017	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLHM3	4000024747	PM01	PLease repiar Autoclave	CSSD 01	Autoclave, Steriliser	0647962	06/06/2016	06/06/2016	CNF TECO	2 - Urgent Work	0
1049	TWVGLHM3	4000118129	PM01	theatre 1-4 auto clave rack repair	CSSD 01	Autoclave, Steriliser	0647962	06/02/2017	26/02/2017	CNF PRT TECO	2 - Urgent Work	
1049	TWVGLHM3	4000157617	PM01	Theatre 1-4 Autoclave faulty	CSSD 01	Autoclave, Steriliser	0647962	28/03/2017	28/03/2017	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLTRN	4000024747	PM01	PLease repiar Autoclave	CSSD 01	Autoclave, Steriliser	0647962	06/06/2016	06/06/2016	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLTRN	4000073123	PM01	Theatre 1-4 ccsd autoclave not working	CSSD 01	Autoclave, Steriliser	0647962	15/11/2016	17/11/2016	CNF PRT TECO	2 - Urgent Work	2
1049	TWVGLTRN	4000088057	PM01	Theatre 1-4 Auto clave faulty	CSSD 01	Autoclave, Steriliser	0647962	14/12/2016	14/12/2016	CNF PRT TECO	2 - Urgent Work	0
						Total days		175			Sum	12
											MTBF	15

Figure 5.6: Data Extracted from CMMS Revealing Autoclave 2 Failures for Hospital 1

MaintP	Work center	Order	Order	Opr. short text	Descriptio	Description2	Sort field	Reference Date	Act.finish date	System Status	Priority	
1049	TWVGLTRN	4000029949	PM01	Autoclave leaking at Th5-7.	CSSD 01	Autoclave, Steriliser	0577888	15/07/2016	02/08/2016	CNF PRT TECO	2 - Urgent Work	18
1049	TWVGLAR1	4000028633	PM01	Replace overload protection	CSSD 01	Autoclave, Steriliser	0577888	05/07/2016	31/10/2016	CNF PRT TECO	2 - Urgent Work	118
1049	TWVGLTRN	4000073122	PM01	Theatre 5-7 autoclave not working	CSSD 01	Autoclave, Steriliser	0577888	15/11/2016	15/11/2016	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLAR3	4000193095	PM01	Theatre 5-7 Autoclave faulty	CSSD 01	Autoclave, Steriliser	0577888	16/05/2017	17/05/2017	CNF PRT TECO	2 - Urgent Work	1
1049	TWVGLAR3	4000327080	PM01	Theatre 5-7 autoclave gasket broken	CSSD 01	Autoclave, Steriliser	0577888	31/08/2017	31/08/2017	CNF PRT TECO	2 - Urgent Work	0
1049	TWVGLHM3	4000327080	PM01		CSSD 01	Autoclave, Steriliser	0577888	31/08/2017	31/08/2017	CNF TECO	2 - Urgent Work	
1049	TWVGLAR2	4000364253	PM01		CSSD 01	Autoclave, Steriliser	0577888	06/10/2017	06/10/2017	CNF TECO	2 - Urgent Work	
1049	TWVGLAR3	4000364253	PM01		CSSD 01	Autoclave, Steriliser	0577888	06/10/2017	06/10/2017	CNF PRT TECO	2 - Urgent Work	
1049	TWVGLHM3	4000364253	PM01	Theatre 5-7 Autoclave faulty	CSSD 01	Autoclave, Steriliser	0577888	06/10/2017	06/10/2017	CNF PRT TECO	2 - Urgent Work	0
						Total time		448			Sum	137
											MTBF	52

Figure 5.7: Data Extracted from CMMS Revealing Autoclave 3 Failures for Hospital 1

Considering that these devices play a central role within the operating theatre complex, offering sterilised instruments to operate with, in a case where all these autoclaves are not available this would render a great challenge to theatre availability. A risk is imposed to patient safety if the instruments are not correctly sterilised due to the malfunction of the autoclave devices.

To address the AM of these devices, SAM would add value due to the fact that current hardware infrastructure within these devices can already be utilised. PLCs are utilised to control these assets, where feedback can obtained to either assist the technician in fault-finding the cause of failure, or furthermore to provide a warning notification where failure is possible.

Air Handling Unit (AHU), is an asset which offers climate control to an operating theatre, however for the case of a laminar air flow theatre (as opposed to a normal fresh air supply), the AHU also plays a critical role in the sterility of a theatre. The rationality behind an AHU is also to provide positive pressure inside a theatre where clean sterile air builds up inside theatre, flowing outward and preventing unclean air coming into the theatre. There are three filters within an AHU where the final HEPA filter is specified to prevent 99.97% of particles that have a size of 0.3 μm. Mechanical manometers are also utilised to measure pressure differentials over the filters to indicate possible leaks as well as particle build-up. Variable speed drives electronically pick up the pressure differential to compensate for the pressure difference ensuring that theatres remain correctly pressurised. The AHU is therefore critical to supporting the environment of theatre, where temperature, pressure and humidity are controlled.

Figure 5.8 and Figure 5.9 below illustrate the MTBF figures for all the AHUs in both hospital 1 and hospital 2, where the CMMS data from hospital 2 is only available from 1 August 2017. As a result the calculated MTBF for hospital 2 is considered higher due to the shorter time frame yet is still considered a good representation of failures experienced. During the 44 day period, there were 8 failures leading to 10 days of unavailability.

Main	Work cent	Order	Ord	Opr. short text	Description	Description2	Barcod	Reference Date	Act.finish date	System Status	Priority	Failure days
1026	TTLPOAR2	4000340856	PM01	please come and check temperature	Critical Care - Ward G	Air Handling Unit	0490691	16/09/2017	17/09/2017	PRT REL	1 - Planned Work	1
1026	TTLPOAR2	4000360318	PM01	Theatre 5 teperature too cold	Theatre 5	Air Handling Unit	0310332	02/10/2017	02/10/2017	CNF PRT TECO	3 - Emergency Work	0
1026	TTLPOHM1	4000369368	PM01	Please set aircon theatre 6 its hot	Theatre 6	Air Handling Unit	0490687	10/10/2017	10/10/2017	CNF PRT TECO	3 - Emergency Work	0
1026	TTLPOTA2	4000383408	PM01	Please clean theatre 7 aircon filter	Theatre 7	Air Handling Unit	0490688	23/10/2017	30/10/2017	PRT REL	2 - Urgent Work	
1026	TTLPOTA2	4000383409	PM01	Please clean theatre 6 aircon filter	Theatre 6	Air Handling Unit	0490687	23/10/2017	30/10/2017	PRT REL	2 - Urgent Work	
1026	TTLPOTA3	4000376279	PM01	Kindly investigate heat in the unit	Critical Care - Ward G	Air Handling Unit	0490691	17/10/2017	26/10/2017	CNF PRT TECO	3 - Emergency Work	9
1026	TTLPOTA2	4000383404	PM01	Please clean theatre 8 aircon filter	Theatre 8	Air Handling Unit	0490689	23/10/2017	27/10/2017	CNF PRT TECO	2 - Urgent Work	
1026	TTLPOTA2	4000383413	PM01	Please clean theatre 5 aircon filter	Theatre 5	Air Handling Unit	0310332	26/10/2017	27/10/2017	CNF PRT TECO	2 - Urgent Work	
1026	TTLPOTA2	4000383416	PM01	Please clean theatre 4 aircon filter	Theatre 4	Air Handling Unit	0429746	23/10/2017	27/10/2017	CNF PRT TECO	2 - Urgent Work	
1026	TTLPOTA2	4000383418	PM01	Please clean theatre 3 aircon filter	Theatre 3	Air Handling Unit	0429745	24/10/2017	27/10/2017	CNF PRT TECO	2 - Urgent Work	
1026	TTLPOTA2	4000383420	PM01	Please clean theatre 2 aircon filter	Theatre 2	Air Handling Unit	0310333	24/10/2017	27/10/2017	CNF PRT TECO	2 - Urgent Work	
1026	TTLPOTA2	4000383429	PM01	Please clean theatre 1 aircon filter	Theatre 1	Air Handling Unit	0310344	24/10/2017	27/10/2017	CNF PRT TECO	2 - Urgent Work	
1026	TTLPOAR2	4000382925	PM01	Theatre 7 cold please adjust temperature	Theatre 7	Air Handling Unit	0490688	30/10/2017	30/10/2017	CNF PRT TECO	3 - Emergency Work	0
1026	TTLPOAR2	4000383727	PM01	Adjust theatre 6 temperature its hot	Theatre 6	Air Handling Unit	0490687	30/10/2017	30/10/2017	CNF PRT TECO	3 - Emergency Work	0
1026	TTLPOAR2	4000384511	PM01	Please adjust temeprature in theatre 5	Theatre 5	Air Handling Unit	0310332	30/10/2017	30/10/2017	CNF PRT TECO	3 - Emergency Work	0
1026	TTLPOAR2	4000384514	PM01	Please adjust temeprature in theatre 6	Theatre 6	Air Handling Unit	0490687	30/10/2017	30/10/2017	CNF PRT TECO	3 - Emergency Work	0
						Total days		44			SUM	10
											MTBF	4

Figure 5.8: Data Extracted from CMMS Revealing AHU MTBF for Hospital 2

To address critical failures of these AHU's, where a majority of the failures are related to temperatures exceeding set points within theatre, back-up compressors are utilised as a fail-safe due to a critical failure of the primary compressor. Both the primary and secondary compressors are specified to be

able to individually handle the cooling requirements of a specific theatre. Due to the availability of the back-up system, the failures listed in Figure 5.8 did not lead to unavailability.

However from the personal experience of the researcher, being involved within hospital 2 during this time period, a critical failure was experienced within theatre 8 where both compressors experienced a failure and the temperature could not be controlled. Compressor 1 failed due to an electrical fault and the back-up compressor had a refrigerant leak and therefore did not have any gas available. In this scenario theatre 8 became unavailable and arrangements needed to be made to accommodate further surgeries. This failure was reported on the CMMS, however the asset barcode utilised is incorrect therefore this major failure has not been correctly recorded on the CMMS. A similar experience is shared within hospital 1 where a component failure on the control board also lead to unavailability of theatre 2 which is not recorded correctly on CMMS as indicated by Figure 5.9.

MaintPlant	Work center	Order	Order Type	Opr. short text	Description	Description2	Barcode	Act.finish date	Reference Date	System Status	Priority	Failure days
1049	TWVGLHM1	4000030615	PM01	AHU4-attend to high pressure.	Plant Room Above Theatres 1 to 4	Air Handling Unit	0164054	20/07/2016	19/07/2016	CNF PRT TECO	2 - Urgent Work	1
1049	TWVGLHM1	4000039878	PM01	Unit noisy.	Plant Room Above Theatres 1 to 4	Air Handling Unit	0164055	31/08/2016	30/08/2016	CNF PRT TECO	2 - Urgent Work	1
1049	TWVGLHM1	4000093466	PM01	AHU not operatingin theatre 4.	Plant Room Above Theatres 1 to 4	Air Handling Unit	0164054	29/12/2016	28/12/2016	CNF PRT TECO	2 - Urgent Work	1
1049	TWVGLAR1	4000024285	PM01	Investigate low pressure.	Plant Room Above Theatres 5 to 7	Air Handling Unit	0577496	10/03/2017	01/11/2016	CNF PRT TECO	2 - Urgent Work	
1049	TWVGLAR1	4000066783	PM01	Investigate low pressure.	Plant Room Above Theatres 5 to 7	Air Handling Unit	0577496	17/03/2017	17/03/2017	CNF PRT TECO	2 - Urgent Work	
1049	TWVGLHM1	4000126956	PM01	Attend to gas leaks - AHU#1	Plant Room Above Theatres 1 to 4	Air Handling Unit	0164051	23/03/2017	16/02/2017	CNF PRT TECO	3 - Emergency Work	35
1049	TWVGLAR1	4000362230	PM01		Plant Room Above Theatres 1 to 4	Air Handling Unit	0164051	07/10/2017	03/10/2017	CNF TECO	1 - Planned Work	
1049	TWVGLHM1	4000362230	PM01	Aircon not cooling - Theatre 1	Plant Room Above Theatres 1 to 4	Air Handling Unit	0164051	07/10/2017	03/10/2017	CNF PRT TECO	1 - Planned Work	4
1049	TWVGLHM1	4000370024	PM01	Store room temperature too high - Old	Plant Room Above Theatres 1 to 4	Air Handling Unit	0164054	13/10/2017	09/10/2017	CNF PRT TECO	1 - Planned Work	4
1049	TWVGLHM1	4000376574	PM01	Aircon Leaking - Theatre 5 (Done 11 Oct	Plant Room Above Theatres 5 to 7	Air Handling Unit	0164089	20/10/2017	11/10/2017	CNF PRT TECO	1 - Planned Work	9
											sum	55
						Total days		458			MTBF	58

Figure 5.9: Data Extracted from CMMS Revealing AHU MTBF for Hospital 1

Within these identified cases for both hospital 1 and hospital 2 the AHUs utilise a controller unit, similar to a PLC, where this device is capable of reporting faults as well as monitor conditions of the AHU. This networked device is also capable of being integrated in a SAM system in order to accumulate historic as well as instantaneous data where this information can provide feedback concerning failure as well as assist in addressing unavailability through keeping specific details of failure. It is also evident that the record of failure is currently incorrectly recorded in the CMMS, as displayed by Figure 5.9 and Figure 5.8 and the researchers personal experiences.

Another important asset identified within the homogeneous interviews is the Uninterrupted Power Supply (UPS) which is a critical to the infrastructure support of a hospital as well as specifically an operating theatre. This asset is central to supporting the electrical reticulation in combination with a generator. The MC group utilises two generators handling two different types of load, referred to as the essential and non-essential load. In the event that an essential generator is unable to handle the load or fails, the non-essential

loads are shed and this generator is then bus-coupled to carry the essential load. This scenario creates a backup for the generator and the electrical reticulation. The UPS plays a key role in supporting the power until such time that the generator is able to start after a power failure and carry the electrical load. Illustrated in Figure 5.10, this displays both breakdown and service work orders for the a single UPS within hospital 2. The UPS undergoes a monthly test, a yearly service and depending on the battery type, a five- or ten-yearly battery replacement.

MaintPlant	Work center	Order	Order Type	Opr. short text	Description	Description2	Sort field	Reference D	System Status
1026	TTLPOAR1	4000303258	PM02	UPS004A Monthly Inspection	Technical	Uninterrupted Power Supply, 3	0597980	10/08/2017	CNF PRT TECO
1026	TTLPOAR1	4000330911	PM02	UPS004A Monthly Inspection	Technical	Uninterrupted Power Supply, 3	0597980	13/09/2017	CNF PRT TECO
1026	TTLPOAR1	4000340325	PM01	inspection to be done with contractors	Technical	Uninterrupted Power Supply, 3	0597980	02/10/2017	CNF PRT TECO
1026	TTLPOAR1	4000359953	PM02	UPS004A Monthly Inspection	Technical	Uninterrupted Power Supply, 3	0597980	24/10/2017	CNF PRT REL
1026	TTLPOAR1	4000390645	PM02	UPS004A Monthly Inspection	Technical	Uninterrupted Power Supply, 3	0597980	21/11/2017	PRT REL

Figure 5.10: Data Extracted from CMMS Revealing UPS Work Orders for Hospital 2

From the work orders received, as displayed in Figure 5.10, this UPS does not highlight any critical asset failure where the CMMS displays only routine maintenance. However, utilising the personal experience of the researcher, a critical failure has occurred during the report period displayed in this figure. This failure was discovered during a routine monthly test, where due to the battery capacity failure the UPS was not able to handle the required load. Therefore the details of the failure as well as the repair are captured on CMMS however a separate breakdown was not reported. This information becomes difficult to find, unless you know specifically what you are looking for. Automated MTBF reports created by the CMMS will also not display or flag this critical failure.

Furthermore another specific example from the researcher's personal experience, from hospital 1, is appropriate. Due to contract work inside a plant room a critical error occurred rendering the UPS unavailable in the event of a power failure. The error was discovered during a routine daily check and was urgently rectified, however no information was captured on CMMS. The standard UPS utilised within the MC group has a specific controller which is capable of serial or network communication. This networked device is also capable of being integrated in a SAM system in order to accumulate historic as well as instantaneous data where this information can provide feedback concerning failure as well as assist in addressing unavailability through keeping specific details of failure. Therefore currently these assets are underutilised where information from CMMS is also not reliable to report on faults experienced.

Another example of the CMMS's inefficiency to report failure of life support equipment is displayed in Figure 5.11, which is flagged as a critical life support asset. The quantity of failures concerning life-support equipment are reported monthly by the technical managers, as part of their KPIs. This figure is withdrawn from a virtual barcode created for failures concerning electrical reticulation. However from the work orders received, various issues, which are remotely related to electrical reticulation are reported by end users within the hospital. The breakdown report includes; plugs not working, patient televisions out of order, nurse call units not working, electronic locks to be replaced and microwaves out of order. The majority of these failures are not related to any critical failure of life support equipment. Therefore the effect of identifying life-support failure is lost with irrelevant data. Furthermore by looking at the overall quantity within the KPI's, this figure does not contribute to addressing critical failures which have not been reported correctly in the first place.

Main	Work center	Order	Order T	Opr. short text	Description	Description2	Referen	System Status	Priority
1049	TWVGLAR1	4000022712	PM01	Electricity off in Kitchen	Workshop	Electrical Reticulation	19/07/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR1	4000024096	PM01	elecrical bord	Workshop	Electrical Reticulation	01/11/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR2	4000041922	PM01	L 15 - L 17 plugs not working	Workshop	Electrical Reticulation	13/09/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR2	4000046507	PM01	L 22 - plugs to be fixed	Workshop	Electrical Reticulation	19/09/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR2	4000046663	PM01	I ward wall plug not working MICU passag	Workshop	Electrical Reticulation	19/09/2016	CNF PRT TECO	3 - Emergency Work
1049	TWVGLAR2	4000084702	PM01	L 9 - cables by headboard hanging out	Workshop	Electrical Reticulation	14/12/2016	CNF PRT TECO	3 - Emergency Work
1049	TWVGLAR2	4000120892	PM01	plug is out of order M1	Workshop	Electrical Reticulation	23/02/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR2	4000129794	PM01	extention plug	Workshop	Electrical Reticulation	08/03/2017	CNF PRT TECO	1 - Planned Work
1049	TWVGLAR2	4000169560	PM01	Please check emergency bell going off	Workshop	Electrical Reticulation	09/05/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR3	4000056479	PM01	radiology computer keeps switching off	Workshop	Electrical Reticulation	11/10/2016	CNF PRT TECO	3 - Emergency Work
1049	TWVGLAR3	4000115333	PM01	Wires to be neatened up	Workshop	Electrical Reticulation	01/06/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR3	4000135882	PM01	repair nurse call panel in office	Workshop	Electrical Reticulation	03/03/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR3	4000161713	PM01	Repair nurse call front office	Workshop	Electrical Reticulation	06/04/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLAR3	4000169260	PM01	Nurse call bells dont show on screen	Workshop	Electrical Reticulation	18/04/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLCT1	4000024388	PM01	Wires exposed of incubator.	Workshop	Electrical Reticulation	21/06/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLHM2	4000022744	PM01	Replace lock to pathcare DB	Workshop	Electrical Reticulation	19/05/2016	CNF TECO	2 - Urgent Work
1049	TWVGLHM3	4000110190	PM01	Microwave oven tripping the electricity	Workshop	Electrical Reticulation	01/02/2017	CNF PRT TECO	2 - Urgent Work
1049	TWVGLTA2	4000029777	PM01	L16-television sound faulty	Workshop	Electrical Reticulation	19/07/2016	CNF PRT TECO	3 - Emergency Work
1049	TWVGLTA2	4000052634	PM01	please fix tv cables under tv L25	Workshop	Electrical Reticulation	11/10/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLTA3	4000068139	PM01	TV L 30 not working repair	Workshop	Electrical Reticulation	09/11/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLTA3	4000073276	PM01	Ligt and Tv goes on and off L2	Workshop	Electrical Reticulation	24/11/2016	CNF PRT TECO	2 - Urgent Work
1049	TWVGLTRN	4000024280	PM01	Light switch making ZZZZZ sound	Workshop	Electrical Reticulation	08/06/2016	CNF PRT TECO	2 - Urgent Work

Figure 5.11: Data Extracted from CMMS Revealing Electrical Reticulation for Work Orders in Hospital 1

From the various examples supplied within this section, it is evident that CMMS as a reporting tool works well when the correct information is supplied to the system. However in the identified cases supplied from the researcher's personal experiences, critical failures occur without being correctly monitored and not being correctly captured. Therefore although the failure was dealt with and a solution was created, from an analysis point of view poor records are kept on CMMS of the correct number of critical failures. The issue is related to human intervention which is required to correctly capture the information, where by human nature faults occur. To eliminate human intervention with respect to reporting faults, a system with principles identified in SAM could be utilised to correctly report faults from capable assets where a true indication of the number of faults and a true reflection of MTBF can be recorded.

5.6.1.3 Administrative Hospital Information

Administrative information regarding the hospital occupancy has been retrieved from two hospitals within the group where an illustration of the typical hospital bed occupancy as well as occupancy of beds derived from theatre utilisation is shown. Table 5.3 illustrates these figures where theatre utilisation is based on the reported theatre time utilised, where the available theatre time is calculated for the total number of available theatres, utilising a typical twelve-hour working day and Sunday work excluded (although emergency cases are conducted).

Table 5.3: Summary of Operating Theatre Utilisation from Two Hospitals

Hospital	*Bed Occupancy (%)*	*Theatre Occupancy (%)*	*Theatre Utilisation (%)*
1	74	55	37
2	87	55	51

From this table it is evident that a large portion of the bed occupancy is derived from patients who enter the hospital as a result of requiring time in theatre, the other patients admitted are referred to as medical patients where they are admitted in serious cases to ICU or the medical ward. Where according to reported figures from the hospital 2, theatre financial turnover per day is typically 250% higher compared to the financial daily bed turnover. Patients who enter theatre are also charged per minute within the theatre where the average time per patient is 60 minutes. Therefore the theatre is regarded as a large income source within the private hospital environment where its financial turnover is based on utilising the maximum theatre time available.

5.6.2 Face Validation

As the name implies this literal concept, *face validation* is further explored by asking the question; *"On the face of things, do the investigators reach the correct conclusions?"* (Gaber, 2010). The term face validity can be considered as a test of internal validity, where this process requires the researcher to view the research processes from an external user's viewpoint. The researcher is, according to Gaber (2010), required to step outside of the current research context and assess the research observations from a common sense perspective. An appropriate application of face validity is concerned with the research obtaining assessments from current or future individuals who will be directly affected by the research findings.

Furthermore according to Borenstein (1998), face validation can be considered as having the following main objective; *"face validation is to achieve consistency between the designer's view and the potential user's view of the problem in a timely and cost effective way. More specifically, face validation ensures that the formulated problem contains the entire actual problem and is sufficiently well structured that a credible solution can be derived before extensive and detailed software development proceeds"*. Borenstein (1998)'s definition of face validation is in fact captured in a greater understanding of a validation process specifically implemented for Decision Support Systems (DSS).

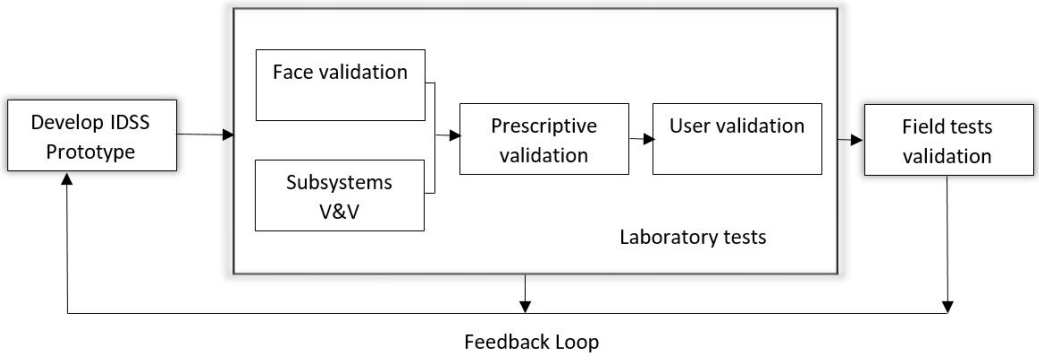


Figure 5.12: IDSS Life Cycle with Emphasis on Validation Process

Adapted from (Borenstein, 1998)

Borenstein (1998) further specifies a practical method for evaluating a DSS through a two stage procedure. This procedure is visually illustrated by Figure 5.12. The first component of the model involves laboratory testing ensuring; face validity, subsystems verification and validation (V&V), and predictive validation. Secondly, the process is concluded with field testing. This DSS life cycle model, with an emphasis on the validation process, is explicitly incorporated into the development life cycle of the DSS prototype under constrained resources of time and costs. This research can to a certain extent be compared to a DSS where the research question addresses appropriate feedback or decision systems to corporate office from an operational viewpoint, at hospital level through implementation of a SAM system. Therefore utilising the Borenstein (1998) model, with respect to a validation processes the researcher is bound by certain time restrictions. Considering the restrained nature of this research, in terms of time to implement the field testing, this validation process considers only the *laboratory* testing.

The face validation questionnaire utilised within this research is therefore based on an extract from the case study conducted by Borenstein (1998) con-

cerning a prototype Intelligent DSS for the evaluation and analysis of flexible manufacturing system design configurations. Borenstein (1998) considers six questions within the face validation process concerning the utilisation of variant DSS, where the researcher has adapted these questions and adopted them within Appendix A.2. The following feedback concepts are required from the participant; Research methodology agreement, opinion concerning strong point, opinion concerning weak points, potential implementation, methods for gathering the research data, possibility of improving the study.

5.6.3 User Validation

Following the Borenstein (1998) validation process, the second set of questions is part of a user validation process. The user validation process should be directed to *interested parties who were not involved in a model's origins, development, and implementation.* Furthermore this process's main objective is to test and obtain a statement of the applicability of the system. Considering these requirements, the heterogeneous group was considered an appropriate group to utilise as part of the user validation process, this sample group clearly resonates with Borenstein (1998)'s directive of participant qualification. However within the process of the defined user validation, the researcher diverged from the case study questions which Borenstein (1998) utilised and created a new set of questions.

This set of questions is used to further probe the creation of a resultant policy, proposing a policy for the implementation procedure regarding the use of SAM within the MC group. Therefore the user validation questions are regarding the application of the SAM concept and its implementation within the private healthcare group. These questions are visible in Appendix A.2, where the resultant feedback is further discussed in section 5.6.4, which elaborates the creation of the policy document as well as the feedback retrieved from this user validation process.

5.6.4 Heterogeneous interview analysis

The heterogeneous interview is conducted as a means to validate the research conducted, where feedback is obtained from technical specialists in the field of engineering management. Selection of these candidates is further described in section 5.2.2 where this section provides feedback concerning a telephonic interview with each of the participants. The questions are outlined as in Appendix A.2, where the transcription of the interview is available in Appendix E.1 - E.3. Section 5.6.4.1 - 5.6.4.3 will furthermore provide a summary of their feedback.

5.6.4.1 Feedback from Candidate One

Of the three candidates interviewed, the general feedback from candidate 1 was the most positive toward the research and the possibility of utilising the created SAM policy document. This candidate also considered the conducted research to be comprehensive with regard to factual content as well as being appropriate within Mediclinic group, where he described the proposed policy document to be informative and currently required. Candidate 1 also proposed that the policy document be utilised as a guideline and furthermore proposed a checklist to be utilised to possibly audit hospitals to ensure the implementation of SAM is according to Mediclinic guidelines and standard. Furthermore it is evident from the discussion with this candidate that he was currently driving the implementation of monitoring devices such as SCADA, within his region where he has a clear impression of what he wants to achieve with the group of technical managers reporting to him.

The candidate proposed concerns regarding the training of technical managers with regard to the implementation of SAM, where he personally felt that the utilisation of a SAM system is for the benefit of the technical manager to make more informed decisions and less so to be utilised by an artisan to observe the asset to see when a failure occurs. Candidate 1 also shared further ideas outside of the research study with regard to utilising SAM to further manage asset tracking, where records of mobile critical assets should be kept as well as facility management in terms of monitoring efficiency of resources. Candidate 1's validation interview can be found in Appendix E.1.

5.6.4.2 Feedback from Candidate Two

Feedback retrieved from candidate 2 was diverse where the candidate felt that the research was fair and agreed that structure was required to formalise the process of implementing SAM. However this candidate felt that the research should have included further life-support equipment utilised within theatre, where the assets affecting the infrastructure of operating theatres is not inclusive enough. The candidate also felt general knowledge was lost due to new workforce members not knowing where to find information.

Although the candidate agreed that the document was factual in content and applicable to the industry, he had reservations regarding whether the document could be implemented within the MC group. He agreed that the concept could contribute value-adding concepts within the group, however he felt that it may be too extreme. The candidate commented that this type of research suited a newer generation, where he felt that certain existing aspects were left behind.

The candidate felt this although he was informed that the proposed document included reference to existing documentation, where the proposed policy document was an additional supporting document. The candidate continued to emphasise the need to update the existing documentation which detailed the operational management strategy of the MC technical group. Candidate revealed that the original documentation was based on technology which was currently not used and has become outdated and should therefore be reviewed. Candidate discussed the use of a reviewing tool to emphasis the changes made which highlights the areas which have changed and to be further reviewed by technical management to incorporate specific new concepts of SAM.

Additionally the candidate reflected on a concept of factoring the possibility of the mobility of the system, where CMMS can be taken to the asset. According to the candidate this is useful where additional information is required, such as reading more information like usage and detecting abnormalities and integrating that within CMMS to create specific notifications. Candidate 2's validation interview can be found in Appendix E.2.

5.6.4.3 Feedback from Candidate Three

The general feedback retrieved form candidate 3 highlighted the fact that this candidate felt the proposed policy document is a bold document that is too academically orientated. Although agreeing that the document is factual as well as required within the MC group he added that according to him it lacked specific details for the implementation of SAM. The feedback the candidate presented was concerned with the fact that, the policy document lacked certain details which the technical managers could misinterpret within the document. The candidate referred to a conceived *romantic notion* interpreted by technical managers where the focus is not clear enough.

The candidate agreed that the document is usable within the group however required certain changes to be implemented, such as adding specific details concerning the exact implementation of SAM on each specific asset. Furthermore the candidate reiterated that the policy document is in its infancy. However the candidate did agree that the research was starting to put structure, by creating a policy document and applying formality to something, according to the candidate, which has gone rouge at the moment. The candidate further explains that the document will need to go through many iterations before it can be implemented, where implementing this user policy would add long-term value.

The candidate further agrees that the proposed implementation policy is a start to a complicated subject which requires further work and input from

regional technical managers. The current document provides a good overview and insight into SAM purpose and concept. However the candidate feels the document needs to pinpoint very specific details for implementation by technical managers within the group. Candidate 3's validation interview can be found in Appendix E.3.

5.6.4.4 Feedback Deductions

The overall feedback from the three candidates was generally positive, where each candidate indicated that a policy document within the MC group is required and that a framework needs to be established towards the implementation of SAM. The candidates also agreed that research conducted was factual in content where the research methodology was applicable to the subject being investigate.

The proposed policy document itself was considered by two of the three candidates as still a work in progress where the document required further refinement before it could be implemented, however agreement was reached that the concept of SAM implementation within the private healthcare group would add value. One candidate referred to the policy document as "visionary", with further reference to the concept as being applicable to a future workforce. Each candidate realised the future potential of this concept where awareness was created regarding how the SAM concept needed to be further managed within the group.

Due to time constraints the researcher is unable to further facilitate the actual implementation of the policy document, where various iterations and processes are required external to the research being conducted to implement this document. However considering the purpose of the validation process, this initial version of the policy document is therefore considered as an achievement of the required goal. Agreement from all three candidates was reached for the requirement of the document. Although reservations exist regarding whether it is usable in its current format the content and research methodology of the document was deemed correct.

5.7 Chapter Summary

This section of the research study comprises the analysis concerning data which was collected within two sets of interviews. These two interviews consisted of a structured questionnaire as well as a face validation process to validate the information gathered within the fieldwork process. The methodology used to process this information is outlined to provide a transparent approach to the findings established, where a thematic analysis technique is utilised to

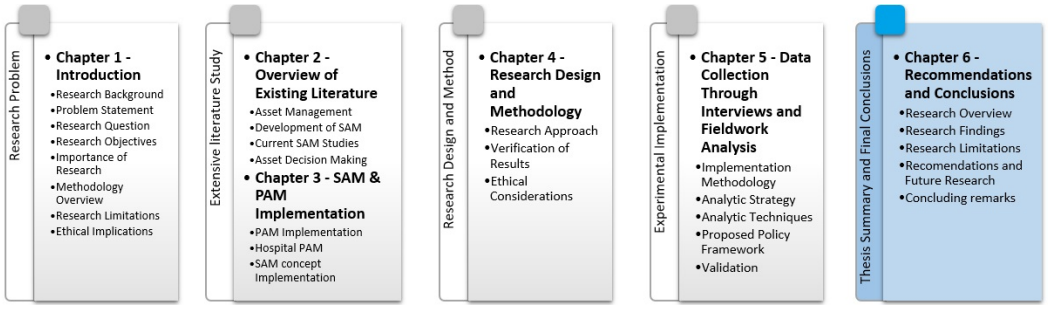
constructively produce findings relevant to the research study. The use of a CAQDAS was determined to not be required due to the relatively small amount of data which was analysed. The researcher chose to complete the analysis utilising a prescribed manual approach, yielding codes and themes as discussed within section 5.4.2.

After conducting the initial homogeneous questionnaire, the resultant conclusion of the analysis highlighted the need for electronic monitoring of critical assets. Within this requirement lies the need for an implementation framework, which was created as a policy document to be implemented within a private healthcare group. This document is set out to prescribe SAM standard operating procedures for implementing electronic monitoring systems such as SCADA and auxiliary equipment.

Archival records were used to verify the data analysed, where the second heterogeneous interview is conducted as a validation process to agree the value contribution of the MC policy document created as a possible means to address the research findings. The final section of this research study is used to conclude the research conducted with further recommendations for future research.

Chapter 6

Recommendations and Conclusions



Chapter Aims:

The aim of this chapter is to summarise and conclude the research presented within this research study; where the ground work, methodologies and analyses has been established in the previous sections. This section will conclude the key research findings by consolidating the research outputs based on the original research objectives. Furthermore recommendations of the research as well as proposed further research endeavours will be elaborated where the research ends with concluding remarks.

Chapter Outcomes:

- Deliberate research findings
- Elaborate on the further recommendations
- Discuss future research possibilities
- Conclude the research conducted

6.1 Chapter Introduction and Research Overview

This concluding chapter to the research is the final step toward submitting feedback from the original problem statement provided in section 1.3. Arising from this problem statement, further investigation was conducted pertaining to AM approaches within the private healthcare sector, with further references to PAM principles. From this literature review an approach to AM namely, SAM was highlighted as a possible means of enhancing the current field of PAM. A specific methodology is created to investigate this research study by utilising a qualitative case study approach, where various sources of information are utilised to investigate an appropriate research solution.

These sources of information include a homogeneous questionnaire where technical managers are questioned within a private healthcare group to determine their experiences about critical assets supporting operating theatres. Archival records are also utilised to demonstrate the current information available concerning critical assets retrieved from the CMMS, furthermore administrative information was also utilised to verify data gathered. A proposed solution was then presented in the form of a policy document describing a SAM implementation methodology within this private healthcare group. A heterogeneous interview was conducted amongst regional technical operation managers using a face validation approach to verify the document as an appropriate solution to the defined research problem.

Within this chapter the research findings according to the outlined process above will be further examined to provide a conclusion to the research conducted. After the research findings have been discussed in section 6.2, opportunities and recommendations for future research will be addressed in section 6.4, which is applicable to the research study. However this was not able to be conducted by the researcher. Finally the research study will be concluded with closing remarks from the study in section 6.5.

6.2 Research Findings

In this final section of the research study, feedback is further interpreted with the knowledge of the overall approach utilised in conducting this research. Within section 5.4, the research analysis is conducted as a means to interpret the feedback collected within the data gathering approaches. Hence assertions can be developed from the insight of the research conducted, discussing the findings in terms of having already established the foundation on which to make these final conclusions. The research findings will further be addressed

systematically, as conducted within the research where an overall conclusion can be drawn considering the positive aspects of the research as well as the limitations, addressed in section 6.3.

Research Conducted From the initial literature study conducted, it is evident that no clear definition or implementation strategy for SAM exists. Addressing the basic notion that this proposed SAM strategy for managing physical assets is a newly defined research topic, SAM is considered a concept integrated within the literature of established physical asset management principles. A variety of similar sources exists in industry which aim toward achieving related goals, namely the establishment of a communication infrastructure within organisational assets to achieve more information and greater control. These sources are from organisations indicating SAM implementation as part of their value proposition, but little academic research could be found. Therefore a research agenda was required to investigate the related concepts to SAM (Nel and Jooste, 2016).

From the literature investigated, it is also evident regarding the numerous benefits which can be derived from implementing PAM best practices, where terms such as asset management excellence and organisations defined as best in class, illustrate the benefits of applying SAM principles. Therefore the proposed concept of SAM, applied from within existing PAM principles illustrates the potential to add value. Therefore building on existing principles defined within the literature study an implementation procedure was investigated to be applied within the private healthcare sector.

Theoretical SAM implementation From the established definition in section 2, the methodology behind implementing SAM is established in section 3 where the interpretation of SAM is not considered a matter of automating each and every process, or making each asset within an organisation a smart asset. Rather an understanding needed to be created to achieving better PAM results through implementing SAM and hence improving the quality of decisions made in order to assist with mitigating critical asset failures. Therefore utilising this methodology, the research study proposed a singular concept definition which incorporated smart technology within asset management and motivated a theoretical definition regarding the implementation of SAM as well as practically applying this concept within the private healthcare industry.

Critical assets identified Following the established research methodology in section 4, the structured questionnaire was created to identify experiences from technical managers concerning departments within the hospital environment which were the most strategic in terms of a maintenance critical approach as well as an economic importance. The operating theatre was identified as

the most important where assets which led to theatre unavailability were then further identified. Furthermore the questionnaire was used to establish specific assets which are critical to supporting the infrastructure of an operating theatre where these assets are identified in section 5. From this homogeneous questionnaire, the identified critical assets were investigated further using archival information from the CMMS. The information extracted from the CMMS illustrated that due to various human interventions, critical asset failures were not appropriately measured and further intervention was required to identify and record critical asset failure.

Requirement for a SAM policy Having identified that the existing CMMS is inappropriate for reporting of critical system failures, where technical managers further agree that theatre unavailability is not reported, SAM can be further utilised as an alternative to monitoring failure. However SAM is not considered a means to replace CMMS, it rather allows for an additional source of information to verify events where specific components of failure can be directly recorded. The strength of the CMMS is utilised by establishing and recording the preventive maintenance schedules which need to be completed and further recorded regarding the captured completion information. Therefore having established the need to implement a SAM system, an appropriate methodology was created and validated within the private healthcare sector. Although further work is required to physically implement the policy, consensus was reached that the policy document is required within the group and that the proposed document was factually researched and would contribute additional value.

It is therefore viable to state that this research successfully achieved all objectives listed in sections 1.3-1.5. The following criteria were met:

1. The fundamental management principles, relevant to the fields of PAM and SAM foundation were established in Chapter 2:
    a) The historical background of both PAM and SAM was reviewed.
    b) The definition for both PAM and SAM was provided.
    c) The fundamental principles required for both PAM and SAM were established
2. The holistic background of the implementation of PAM specific to hospitals and SAM proposed implementation were discussed in Chapter 3:
    a) The implementation principles of a general PAM approach
    b) The historic background of PAM implementation within the hospital environment

c) The theoretic link between the strategic execution of PAM and SAM

d) The proposed SAM implementation methodology

3. A sound, detailed research methodology approach was developed in Chapter 4

   a) The outlining requirements of qualitative research method utilising a case study approach was outlined

   b) A heterogeneous structured questionnaire proposed

   c) Homogeneous interview proposed to be utilised within validation approach

   d) Research verification proposed by utilising additional data sources

4. The proposed SAM implementation framework was established, by utilising the data gathered through the fieldwork analysis in Chapter 5

   a) Research methodology is implemented to establish participants within the research

   b) Data gathered is analysed in a thematic analysis approach where codes from the research is generated and analysed.

   c) Proposed policy document established

   d) Validation conducted on the effectiveness of the proposed policy document

The case study approach utilised within this qualitative research study, assisted the researcher in employing several sources of information to approach the research conducted form multiple viewpoints, generating a holistic view of the required outcomes. Furthermore open-ended questioning within the homogeneous questionnaire allowed first-hand experiences to be retrieved from the operational level within the organisation. Therefore this feedback could be incorporated within the application of a SAM implementation policy. Taking into consideration that the proposed SAM implementation is an innovative approach which lacks a general understanding within industry, the validation process incorporating feedback from regional technical operation managers allowed an introspective view of implementing the proposed SAM policy.

Considering that an implementation framework specific to SAM implementation could not be determined within current literature by the researcher (during the period of research whilst conducting this research study), the development of a framework using the case study analysis provided a practical view of the implementation of SAM. Furthermore operational problems experienced within current daily procedures was highlighted within the research where introducing SAM could address the issues. Considering that some of

the participants within the research were already applying some of the highlighted methodologies, made implementation of the proposed policy likely. The proposed policy provides a guideline to management with respect to a holistic understanding of, and provides consideration for the benefits of as well as concerns for, establishing an effective implementation procedure. Upon implementation, it is believed that SAM incorporation will provide this specific private healthcare group a basis for improving the mitigation of critical system failures within operating theatres.

Limitations experienced within the research will be further addressed, which will further lead to research recommendations as well as proposed future research within section 6.3 and 6.4 respectively.

6.3 Research Limitations

Research methodologies each have their own advantages and limitations, where the utilised case study approach is also subject to traditional prejudices where scholars have challenged the legitimacy of the case study approach and its methods within the social sciences, Yin (2009) further highlights these limitations. However the utilisation of this approach is based on the merits as discussed in section 4.2.4 where one specific limitation will be addressed, with respect to scientific generalisation, which the case study research does not claim to implement.

It is important to note from the outset of this research study, the case study was conducted within a single private healthcare institution. Although various hospitals are represented with the research, the research conducted remains confined, as addressed in the title, to "operating theatres in a private healthcare group". Therefore this study did not claim for a representative of sample, since the results may not be generalised to a larger population. The views expressed by participants within this study do not represent views of all managers in the private healthcare sector within South Africa. This study is limited to the implementation of SAM with a specific private healthcare group within South Africa, as a developing country. Therefore it can be said that results obtained from similar studies within developed countries may vary, where their PAM principles may be perceived differently and explained from a different framework. The case study approach however, is a method which emphasises the view of a specific case. Therefore an investigation is completed within the framework of that specific case in mind where multiple sources may be used within this case to verify the findings. A specific framework with respect to the investigation of this case study is applied, where reputable sources were utilised to guide the research design. Due to this basic set of conditions, a very similar theoretical explanation of SAM implementation should arise from

similar studies within another private healthcare sector, if the same theoretical perspective of the original researcher is utilised. Therefore it is probable that findings from similar research will be consistent with the explanations and emphasis from the specific aspects of SAM implementation which are derived from this study.

Considering the proposed SAM implementation within this specific private healthcare group, it is important to take note that the proposed policy is a specific topic researched for relevancy and should not be seen as the only solution to the gaps identified within the organisation. The policy and the proposed implementation thereof should be considered holistically with respect to the organisational information provided. It is therefore not viable to argue that this research is claimed as the only solution which should be implemented, however evidence has been provided to concur that this study would contribute value. Consideration should rather be given to the comprehensive research investigation which revealed management concepts and considerations required to facilitate the implementation of SAM.

The limitations that were considered within this section, are dealt with throughout the progress of this research study. Furthermore the validity and verification tests conducted within section 5.6, are utilised as specific tools and techniques prescribed within the case study research process to strengthen the findings which were obtained. Addressing these limitations also creates an opportunity for further future research which was not addressed within this research study. These recommendations will be further discussed in section 6.4.

6.4 Recommendations and Future Research

During the research process considerations regarding concepts related to the research being investigated have come to light. These are concepts which are not part of the original research problem being investigated. Therefore to address these relevant considerations, the following recommendations to the research are suggested for future consideration. The following five topics represent these additional suggestions which are recommendations to further the research conducted.

1. Implementation of SAM policy
2. SAM and CMMS Integration
3. Performance Management
4. Predictive Maintenance (PdM)

Implementation of SAM policy The proposed SAM implementation document was not physically implemented within the Mediclinic group, due to the document requiring further review from regional technical operation managers. Therefore the implementation thereof could not be further facilitated by the researcher. In order to accurately establish whether the proposed implementation methodology is successful, SAM needs to be established according to the policy document within the private healthcare environment, where an experimental procedure needs to be created to determine the success of implementing SAM as opposed to not implementing SAM. The research would need to be conducted in such a manner as to control variables ensuring the dependant variable, critical asset failures (or similar variables defining SAM success), is successfully measured.

SAM and CMMS Integration "Bringing CMMS to the asset". As proposed by the defined concept of SAM, the notion to integrate the asset into the virtual realm can be established through integrating CMMS with direct asset feedback. The asset should be able to communicate on a specific platform in order to report its condition and efficiency directly to a CMMS. Within the research study, the concept of CMMS integrated with SAM, is an ideal generated from the possibility of CMMS developers integrating communication from assets within the asset maintenance schedules. The application of this research would need to be addressed by developing an experimental framework where an existing CMMS is compared to a SAM CMMS, where the dependant variable, critical asset failure would need to be measured.

Performance Management From the candidates interviewed within the heterogeneous validation process, all three candidates mentioned the fact that efficiency and resource management of a hospital including plant effectiveness needs to be taken into consideration. The concept of efficiency management is separate to this study. However, it can be included within the SAM implementation. Furthermore concepts such as Overall Equipment Effectiveness (OEE) are appropriate to manage and assess overall asset performance in terms of resource usage and expected output delivery. Specific aspects which could be taken into consideration are; instantaneous monitoring of resource consumption such as mains water and electricity usage, run time of equipment such compressor/vacuum pump running hours and equipment effectiveness such as hot water plant.

Predictive Maintenance The concept of predictive maintenance is also a well-investigated field pertaining to PAM, where the term is related to the ability to pre-empt asset failure. By utilising the concept of SAM, predictive maintenance is a key addition to mitigating critical asset failure where this concept should definately be further incorporated and investigated. Two

specific concepts related to predictive maintenance include, Condition Monitoring (CM) and Statistical Process Control (SPC). The term CM is a concept related to preventative maintenance where information regarding the asset is continuously measured over a specific time frame to compare whether the asset's condition deteriorates from a specified normal value. Physical parameters such as vibration monitoring, temperature and electrical consumption can be measured as conditional reference values. SPC, a concept related to CM, can be defined as a statistical tool which is used to monitor the outputs of an asset's production process in real time in order to detect significant abnormalities/variations before deteriorating into a circumstance which results in system failure. Furthermore, changes can be automatically implemented within the system to avoid such a systematic failure. In order to achieve this the data is continually compared to a lower and an upper limit, where visually the process can be plotted on a graph and the measured data needs to remain between two horizontal lines representing the lower and upper limit. SPC therefore needs to be applied simultaneously to all variables which have been identified to impact on system health.

6.5 Concluding remarks

Utilising a qualitative case study approach with respect to exploring the possibility of implementing SAM to reduce critical asset failures within operating theatres was both a daunting challenge and a rewarding experience. As described through the research the concept of SAM is relatively new concept which needs to be established within literature. Establishing such a new addition to research is a rewarding experience to be able to grow and find out more about the subject as you identify where it comes from and the direction this concept is moving towards.

Following the research methodology as outlined within this research study, the progression within the research study has equipped the researcher with the ability to work systematically through various sources and related literature concepts to establish a specific theory utilising qualitative research methods. Furthermore it provided the researcher with the required tools and strategies to manage the data analysis and interpretation where experiences from other technical managers could be objectively processed within the data analysis. Utilising the prescribed analytic techniques, the researcher was able to objectively work though the qualitative feedback, coding and transcribing results to be processed by further validation and verification techniques to provide objective feedback concerning the work completed. The allowed the researcher to constructively build a valid implementation methodology following sound academic practices.

A final motivation to conclude this research, is the fact that the researcher has found the possibility of implementing SAM an exciting and thought-provoking experience. The possibilities become endless, especially within a time where concepts such as big data, Industry 4.0 and IoT are emerging opportunities of research which need to be implemented and documented within literature studies. The researcher has included these concepts within this research study, as possible implementation methodologies pertaining to PAM as means to encourage new and existing research concepts to embrace these innovative theories and technologies. Hopefully this study has also inspired other researchers to further the research conducted, to promote the greater understanding of this fascinating topic.

Appendices

Appendix A

Structured On-line Questionnaire

A.1 Homogeneous questionnaire

Technical Managers Questionnaire

This questionnaire addresses the research conducted in a thesis presented in partial fulfillment of the requirements for the degree of Master of Engineering Management in the Faculty of Engineering at Stellenbosch University.

TITLE OF THE RESEARCH PROJECT: A Case Study for Integrating Smart Asset Management Within Operating Theaters in a Private Healthcare Group to Mitigate Critical System Failure.

ADDRESS: Department of Industrial Engineering, University of Stellenbosch, Private Bag X1, Matieland, 7602, South Africa.

REFERENCE NUMBER: SU-HSD-004164

RESEARCHER: Charles Benjamin Hirschowitz Nel.

CONTACT NUMBER: 078 639 7072.

* Required

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY CONSENT TO PARTICIPATE IN RESEARCH

Dear Participant,

My name is Charles Nel and I am completing my Masters in Engineering Management from the Industrial Engineering Department at the University of Stellenbosch. I would like to invite you to participate in a research project entitled "A Case Study for Integrating Smart Asset Management Within Operating Theaters in a Private Healthcare Group to Mitigate Critical System Failure".

Please take some time to read the information presented here, which will explain the details of this project. Please do not hesitate to contact me if you require further explanation or clarification of any aspect of the study. Also, your participation is entirely voluntary and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Humanities Research Ethics Committee (HREC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

The purpose of this study is related to the development of a research field known as Physical Asset Management (PAM), where international standards organisations, such as the British Standards Institute (BSI) and the International Standards Organisation (ISO), have contributed to creating frameworks for establishing as well as formulating industry best practices for the management of physical assets.

As identified by the World Healthcare Organisation (WHO), an effective medical equipment maintenance program consists of adequate planning, management and implementation where the administration of healthcare technologies are an essential basis for the correct functionality of an effective healthcare system.

This research study is related toward exploring the qualitative aspects of enhancing operational and corporate management through incorporating technological communication methods to produce asset knowledge enablers allowing better management decisions to be made. It is within this awareness, that this research study is focused on the value contribution of a newly defined concept, Smart Asset Management (SAM) used to integrate sectors of asset information and using asset communication possibilities to improve the strategic maintenance management of operating theaters within the Mediclinic Southern Africa (MCSA) group. This research is conducted in order to assist with the prevention of critical system failures hence overcoming asset unavailability and also addressing competitive pressures of providing healthcare facilities to practitioners who can be considered customers in choosing to utilise MCSA services.

Individuals involved in the data collection will be the researcher (principal investigator) and participants with the knowledge of asset maintenance within operating theaters. These participants include Technical Managers and Technical Supervisors, from MCSA, responsible for ensuring that equipment surrounding theaters are in working condition, where preventive and corrective maintenance is applied.

Please take note that no known risks and/or discomforts, inconvenience, psychological stress and stigmatisation are associated with this study. You are also assured that you will not be treated as objects nor be manipulated in any way. If at any point you should experience any discomfort or have any complaints during the questionnaire, you have the right to stop at any time necessary or contact the researcher and supervisor personally. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. We cannot promise the study will benefit you as an individual, however, your participation will contribute to the gained knowledge and relevance of asset management to the physical asset management industry. If submitted for publication, an acknowledgement will be indicated for the participation of all participants. Unfortunately, you as participant will not receive any payment for participation, but you will receive the researcher's and supervisor's gratitude.

With your permission, this questionnaire will be electronically completed where the researcher will solely have access to the recordings where any communication separate from this questionnaire is welcome and will also be treated with the same conditions as highlighted within this consent participation. This questionnaire will be compared to other responses from participants within the same field, where responses will be further analysed to draw appropriate conclusions. This and any other electronic documentation will be safely stored on a personal computer with a password (no third party will be granted permission to be able to access these documents, it will only be accessible to the researcher). Upon completion of the study, the original questionnaires will be disposed in a confidential manner.

Any findings post completion of the research would be gladly shared with you if you would be interested and requested to do so. Hence, your personal details, documents and records will be kept confidential for research purposes only. Your identity as participant will only be known to the researcher while you will remain anonymous to the other participants throughout the interviews. Your participation to the findings will be accessible to the researcher, supervisor and examiner solely where no data sharing is envisaged. Also, any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

If you have any questions or concerns about the research, please feel free to contact the following:

Charles B. H. Nel (Principal Investigator) Cell: 078 639 7072 E-mail: cbhnel@gmail.com / 15055418@sun.ac.za

Dr. J.L. Jooste (Supervisor) Tel: 021 808 4234 E-mail: wyhan@sun.ac.za

If you are willing to participate in this study please indicate 'YES' within the online questionnaire where declaration of consent is accepted upon prompting the questionnaire to continue.

Yours sincerely

Charles B. H. Nel
(Principal Investigator)

RIGHTS OF RESEARCH PARTICIPANTS:

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.
You have right to receive a copy of the Information and Consent form.

DECLARATION BY PARTICIPANT:

By agreeing to continue with the questionnaire, you as the participant agree to take part in a research study described in the preceding preamble. Furthermore you as the participant agree to take part in this research study conducted by Charles B. H. Nel, master's student at the University of Stellenbosch, Industrial Engineering Department.

By accepting to continue with the questionnaire you declare that, as participant, you understand and agree to the following conditions:

- I have read the attached information leaflet and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.
- All issues related to privacy; confidentiality and the use of information I provide have been explained to my satisfaction.

Particulars of the questionnaire are captured automatically upon completion and the participant agrees to all conditions by choosing to continue with the questionnaire and by so doing electronically affirms acceptance without requiring to sign a physical document.

The principal investigator also declares that information given in this document is not misleading where support can be given if the participant requires it. Otherwise it is further accepted that the participant understands the conditions and is given ample time to complete.

1. **If you have read and understand the "Declaration of Consent", please indicate your willingness to participate in this study by choosing the "accept" option.** *
   Mark only one oval.

   ◯ Accept *Skip to question 2.*
   ◯ Decline *Stop filling out this form.*

Skip to question 2.

Participant Details

Please be assured that these details remain confidential and will not be used for any other reason than stipulated within the consent to participate. Where the participants information is purely used to validate responses.

2. **Participant's Name and Surname**

3. **Participant's Contact Detail - Email**

4. **Participant's Contact Detail - Telephone Number**

5. **Hospital Name**

6. **Participant's Position**
Mark only one oval.

- ◯ Technical Manager
- ◯ Technical Supervisor
- ◯ Other: _____

7. **Number of years experience within current position**

8. **Participant Experience/Background**
Check all that apply.

- ☐ Mechanical
- ☐ Electrical
- ☐ Electronic
- ☐ Industrial
- ☐ Clinical
- ☐ Management / Leadership
- ☐ Computer Science / ICT
- ☐ Construction
- ☐ Plant Manufacturing
- ☐ Research and Design
- ☐ Academic
- ☐ Other: _____

Hospital infrastructure information

Please specify some details concerning your hospital

9. **Please specify the number of beds in your hospital**

10. **Please specify the number of operating theaters you have**

11. **Please specify the number of laminar air flow operating theaters you have, with air handling units**

12. **Please specify the total number of beds you have in all your ICU's**

13. **Please specify the number of beds in your Emergency center**

14. **Is your kitchen externally contracted?**
Mark only one oval.

- Yes
- No
- Other:

Asset Management

This section aims to illustrate the industry standard for asset management.

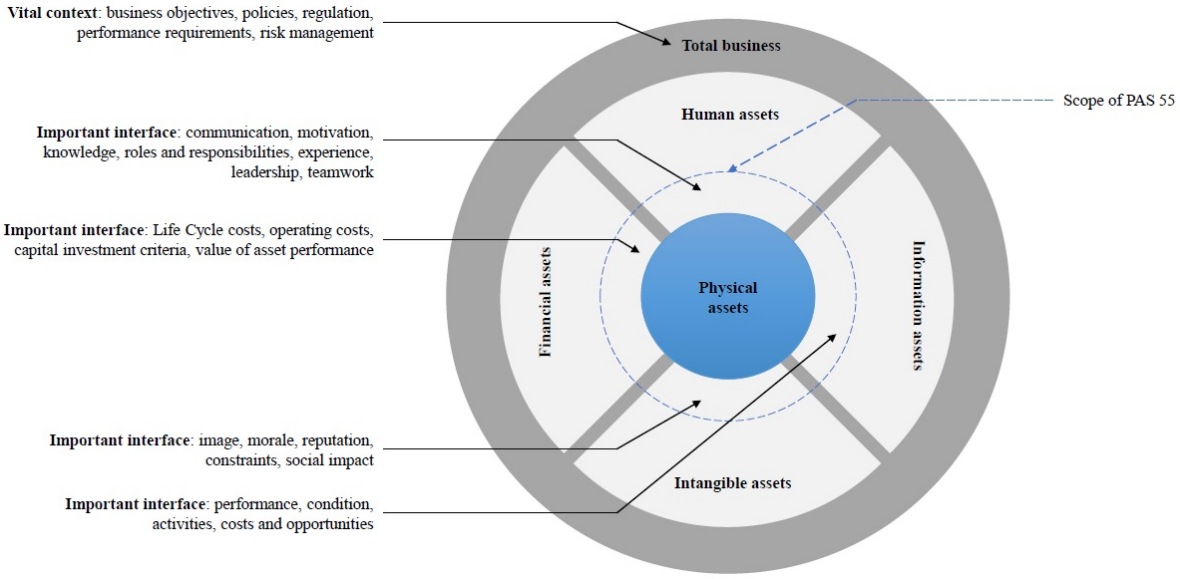
The purpose of this questionnaire and ultimately the study is to delineate the domain and constructs of a concept referred to as Smart Asset Management (SAM), where a strong data driven feedback approach can be used to assist asset managers to better manage critical asset systems. Your contribution is aimed at assisting with the implementation of SAM within the private healthcare industry to address the improvement of strategic asset system availability.

Introduction to Asset Management

An encompassing definition of Asset Management (AM) from the U.S. Department of Transport, defines AM as "… a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short- and long-range planning". This example of AM illustrates the relation of AM to strategic decision making. Asset managers are constantly faced with creating, maintaining and implementing structures used to make decisions concerning the assets they manage.

AM is therefore a management based field of study which incorporates human operational structures for managing people who manage physical assets. The term "asset" also has various references as illustrated in the image below.

Asset Classes



Physical Asset Managment

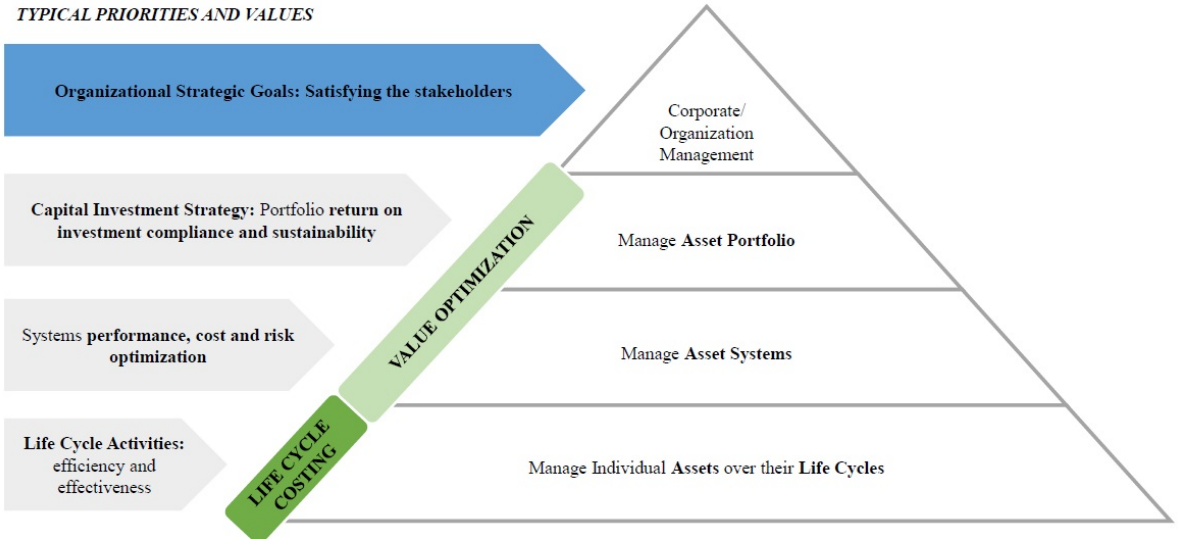
Physical Asset Management (PAM) can therefore be simply explained as the organisational management of physical equipment.

Two well known international standards have been established regarding the management of physical assets, the British Standards Institue (BSI) which has contributed a Public Available Standard (PAS) known as PAS55, and the International Standards Organisation (ISO) has recently developed the ISO 55000 series which governs the management of physical assets.

An asset as defined by ISO 55000 is an: “item, thing or entity that has potential or actual value to an organization”. Where “physical assets usually refer to equipment, inventory and properties owned by the organization. Furthermore the management of these physical assets is defined as the “coordinated activity of an organization to realize value from assets”, “Realization of value will normally involve a balancing of costs, risks, opportunities and performance benefits.” A Strategic Asset Management Plan (SAMP), as used with ISO 55000 is defined as the “documented information that specifies how organizational objectives are to be converted into asset management objectives, the approach for developing asset management plans, and the role of the asset management system in supporting achievement of the asset management objectives”.

The PAS55, a preceding publication to ISO 55000, also highlights AM as a “systematic and co-ordinated activities and practices through which an organization optimally manages its assets, and their associated performance, risks and expenditures over their life cycle for the purpose of achieving its organizational strategic plan”

Asset Priority and Values

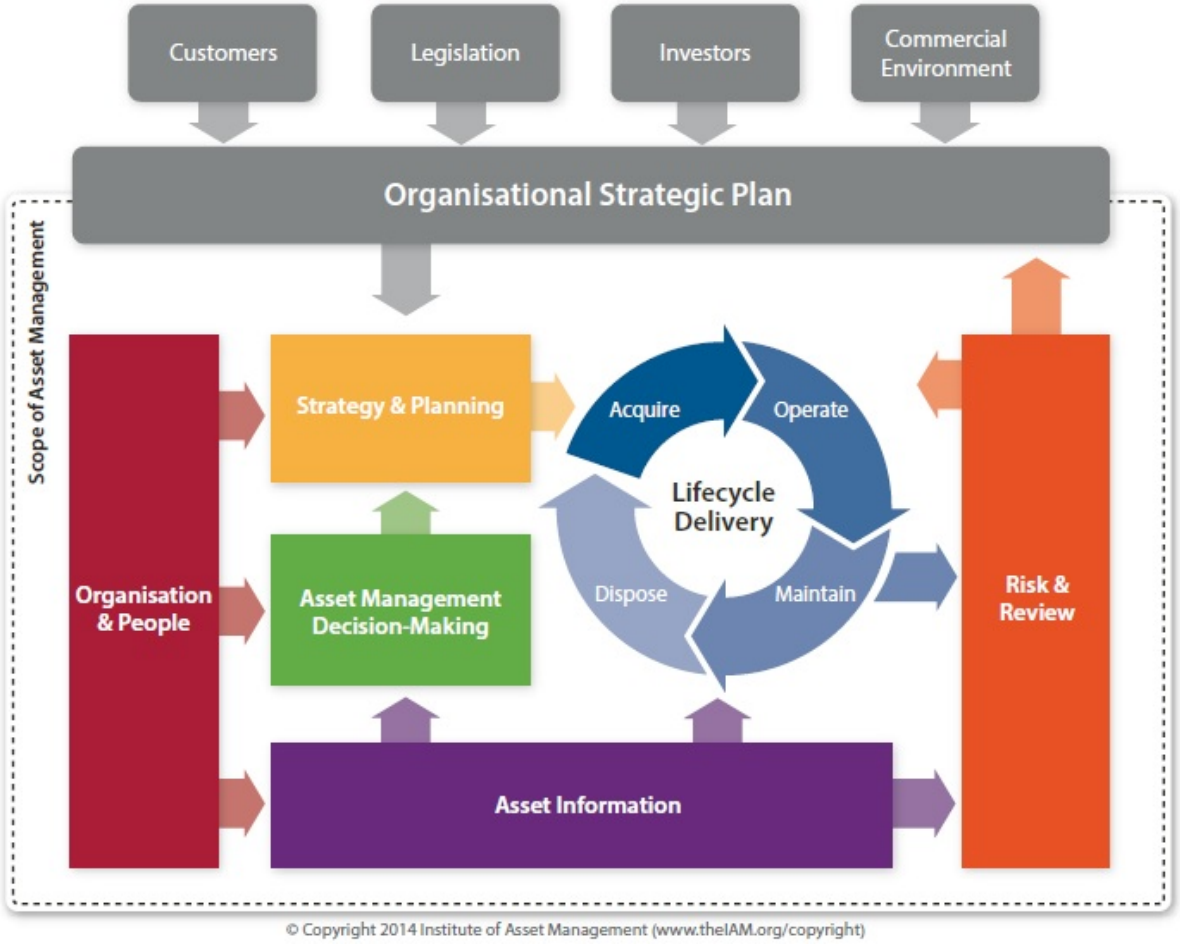


Strategic Asset Information

"You can't manage what you don't measure"

Inherent within any asset management system is the requirement of asset information and feedback systems. As illustrated in the following image - asset information (also referred to as asset knowledge enablers), provides the ability to make more informed decisions and take action with regard to strategic management.

This image illustrates the scope of asset management according to the Institute of Asset Managment



Smart Asset Management

The scope of AM above highlights the inter-relations of various aspects when implementing an AM system. Where these interrelations are often manual processes which require time and energy. The concept Smart Asset Management (SAM), is aimed at automating certain process by combining the ability of technological inter-operablility, between assets and strategic management systems. SAM systems and devices are tools which allow for the collection of information for asset managers to make more informed decisions to take actions which lead to optimal results

15. **Considering the details presented concerning asset management, do you feel that you understand the concept of asset management?**
    You are welcome to select either yes or no, and elaborate your answer within the "Other" category
    Check all that apply.

    - [ ] Yes
    - [ ] No
    - [ ] Other: _____

16. **Considering the definition of asset management, do you understand the role required of an asset manager?**

    You are welcome to select either yes or no, and elaborate your answer within the "Other" category
    Check all that apply.

    - [ ] Yes
    - [ ] No
    - [ ] Other: _____

17. **Considering the definition of asset management, do you agree or disagree that asset management is applicable to your role within the organisiation?**

    You are welcome to select either yes or no, and elaborate your answer within the "Other" category
    Check all that apply.

    - [ ] Yes
    - [ ] No
    - [ ] Other: _____

Implementation of SAM within a Hospital

This section draws on your knowledge of strategic assets within the hospital environment and the management thereof. Where a specific focus has been applied to operating theaters, as one of these asset systems. Where areas are to be identified which can be targeted to improve strategic performance.

Please note that I am aware that various issues exist regarding operational performance and that this study is focusing on a small element of improving asset management within the hospital environment. However please feel free to add suggestions to improve the focus specifically related to this research.

18. **With respect to the definition of asset management, please describe your understanding of the term as well as your implementation thereof in your hospital**

    _____

    _____

    _____

    _____

    _____

19. **Consider the physical infrastructure of your hospital, as well as the physical assets/asset systems which support your facility. Reflect on those assets and asset systems which are critical in nature, please discuss these assets which impact the operational activity of various departments in your hospital**

    _____

    _____

    _____

    _____

    _____

20. **With respect to the previous question, please consider the following departments and rate them in order of infrastructure maintenenace priority, where 5 is the highest priority**

Mark only one oval per row.

	1	2	3	4	5
Administration					
High Care Room					
Medical Wards					
Cardiothoracic Ward					
Emergency Centre					
Operating Theatre					
Pharmacy					
Intensive Care Unit					
Computer Server Room					
Kitchen					

21. **Please elaborate your answer**

22. **Considering the previous question, please consider the same departments and rate them in order of potential economic revenue priority considering the operational revenue aspects of the hospital**

Mark only one oval per row.

	1	2	3	4	5
Administration					
High Care Room					
Medical Wards					
Cardiothoracic Ward					
Emergency Centre					
Operating Theatre					
Pharmacy					
Intensive Care Unit					
Computer Server Room					
Kitchen					

23. **Please elaborate your answer**

24. **Please highlight individual assets within these high priority departments which are strategically critical when considering the department's operational performance**

25. **Considering these individual physical assets, briefly discuss how you are alerted to the malfunction of these critical assets. Please provide specific details if the proposed notification systems are effective in various scenarios or not**

26. **What systems have you put in place to monitor these strategic critical asset systems? Please consider and elaborate if these systems are proactive or reactive to failure**

27. **How do you utilise and manage these systems within your daily work routine?**

28. **Are work orders (job cards) consistently raised by users to report issues effecting critical aspects which can lead to malfunction?**
Check all that apply.

- [ ] Yes
- [ ] No
- [ ] Other:

Please consider the infrastructure and the indiviudal physical assets and asset systems pertaining to specifically an operating

theaters

29. **Please rate the following examples of asset components pertaining to an operating theater in order of priority, where 10 is the highest priority**

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10
Line insulation monitoring device										
Air handling unit / climate control										
Laminar air flow										
Water supply										
Generator power supply										
Oxygen supply										
Isolation transformer										
Autoclaves										
Uninterrupted power supply										
Operating lights										
Vacuum										

30. **Please discuss critical physical asset components effecting the operation of an operating theater which have not been included above, as well as indicating a priority of this component**

31. **In your experience please discuss factors or instances, as well as failure of physical asset components which can lead to the UNAVAILABILITY of an operating theater due to critical asset failure**

32. **Do you specifically keep record of instances involving the unavailability of a theater?**

Mark only one oval.

- Yes
- No
- Other:

33. **If so please elborate**

34. **Are work orders (job cards) consistently raised by users to report issues effecting critical aspects which can lead to theater downtime?**
Mark only one oval.

- Yes
- No

35. **Please elaborate your answer above, where you are welcome to provide examples**

_____

_____

_____

_____

_____

36. **Do you capture electronic data automatically from any of the following monitoring applications impacting your theater?**
Check all that apply.

- [ ] Line isolation monitor
- [ ] Electrical reticulation - Volts / Amps / Power consumption
- [ ] UPS monitoring
- [ ] Generator monitoring
- [ ] Isolation transformer temperature
- [ ] Air handling Unit - Apogee software
- [ ] Water Monitoring
- [ ] Gas monitoring
- [ ] Other: _____

37. **Do you reflect on this information on a routine basis, if so please discuss how and why you do so**

_____

_____

_____

_____

_____

38. **Please discuss proactive applications which monitor critical asset systems which alert you / your department of an impending failure. You are welcome to discuss applications which are or can be utilised if not currently used in practice (please specify accordingly if you do not currently implement such a system)**

39. **Do you feel these monitoring systems can add value to your role within the asset management and managing asset availability within your hospital environment? Please elaborate**

Conclusion

The questionnaire has been completed. This section is used to wrap up any outstanding issues or questions from the participant.

40. **Please feel free to add any comments or suggestions which can be used to improve this questionaire**

Thank you very much for your assistance with regard to this questionaire

I appreciate the time and effort your have put in with regard to completing this survey.

Thank you very much!

A.2 Heterogeneous interview

Research Validation Introduction

This is a supporting document which elaborates the theoretical framework of a research study conducted by Charles Nel concerning “A Case Study for Integrating Smart Asset Management Within Operating Theatres in a Private Healthcare Group to Mitigate Critical System Failure”.

This study entails the delineation of the domain and constructs of a concept referred to as Smart Asset Management (SAM), which refers to a strong data driven feedback approach used to assist asset managers to better manage critical asset systems. Your contribution is aimed at assisting with the validation of this study, where the implementation of SAM within the private healthcare industry is investigated to addressing and ultimately improve the strategic aspects of asset infrastructure efficiency and availability.

This document sets out to elaborate the context of the research study as well as the research methodology to provide insight into the entire proses. Once this has been established, the aim of this proses is for the research conducted to be validated in a face validation proses. This face validation concept is defined as “looking at the face value of the research conducted”, where key role players and experts in the field are chosen to provide their professional opinion concerning the viability research conducted.

As a participant within this face validation proses, you agree to read through this document, where a predetermined date for a telephonic interview will be arranged to address a short verbal presentation, after which your feedback will be captured through a series of standard questions found in the final section of this document.

1. Asset Management background

This section aims to define as well as illustrate the industry standard for the study of asset management as well as related concepts.

1.1. Introduction to Asset Management

An encompassing definition of Asset Management (AM) from the U.S. Department of Transport, defines AM as “… a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short- and long-range planning”. This example of AM illustrates the relation of AM to strategic decision making. Asset managers are constantly faced with creating, maintaining and implementing structures used to make decisions concerning the assets they manage. AM is therefore a management based field of study which incorporates human operational structures for managing people who manage physical assets. The term "asset" also has various references as illustrated in figure 1. Therefore the term asset management appropriate to technical operations within MC would refer to the physical assets being managed.

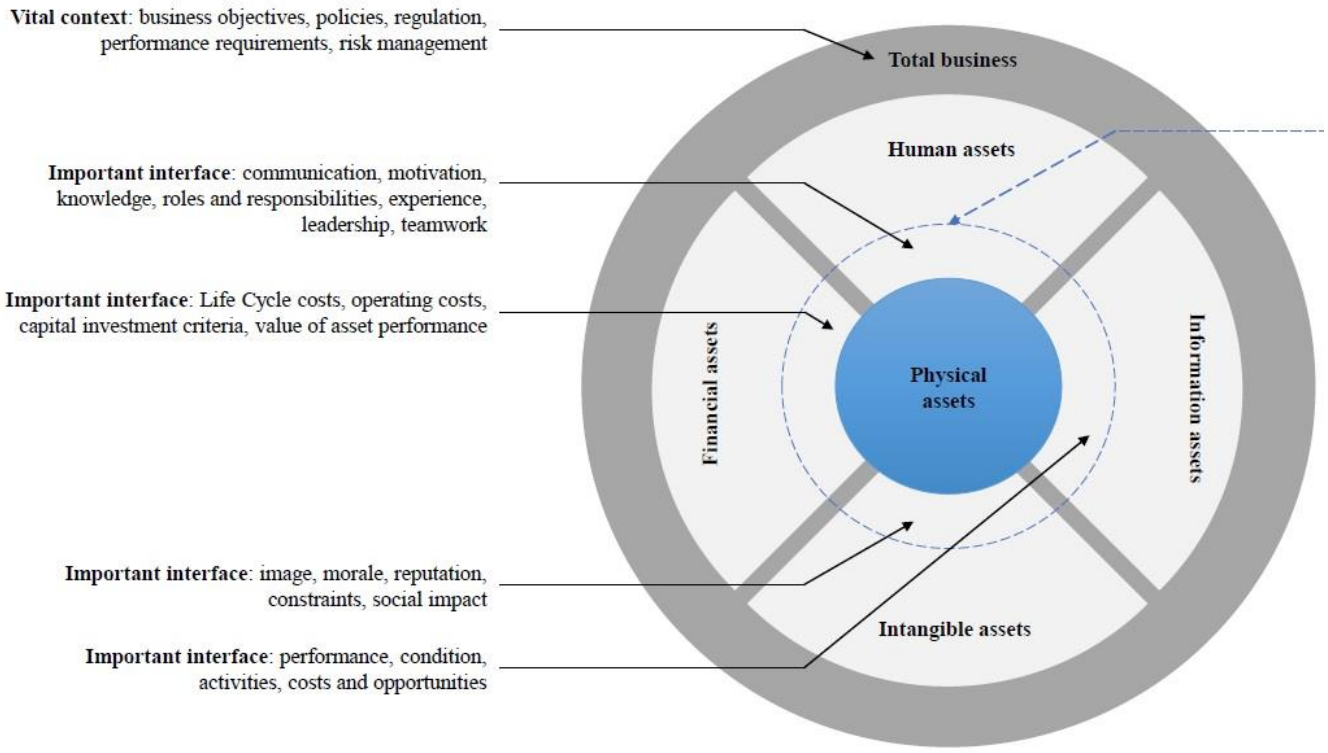


Figure 1: Various asset structures involved with asset management

1.2. Physical Asset Management

Physical Asset Management (PAM) can therefore be simply explained as the organisational management of physical equipment.

Two well-known international standards have been established regarding the management of physical assets, the British Standards Institute (BSI) which has contributed a Public Available Standard (PAS) known as PAS55, and the International Standards Organisation (ISO) has recently (in 2015) developed the ISO 55000 series which governs the management of physical assets. An asset as defined by ISO 55000 is an: “item, thing or entity that has potential or actual value to an organization”. Where “physical assets usually refer to equipment, inventory and properties owned by the organization. Furthermore, the management of these physical assets is defined as the “coordinated activity of an organization to realize value from assets”, “Realization of value will normally involve a balancing of costs, risks, opportunities and performance benefits.”

A Strategic Asset Management Plan (SAMP), as used with ISO 55000 is defined as the “documented information that specifies how organizational objectives are to be converted into asset management objectives, the approach for developing asset management plans, and the role of the asset management system in supporting achievement of the asset management objectives”. The PAS55, a preceding publication to ISO 55000, also highlights AM as a “systematic and co-ordinated activities and practices through which an organization optimally manages its assets, and their associated performance, risks and expenditures over their life cycle for the purpose of achieving its organizational strategic plan”.

Figure 2 below shows the value propagation of such PAM systems. Where the value optimisation of asset systems, lies in managing the system performance and cost optimization. Similarly the capital investment of these improvement strategies to assist in managing not a single operational event or single entity but rather a managing on an organisational level effecting the strategic decisions of the asset portfolio.

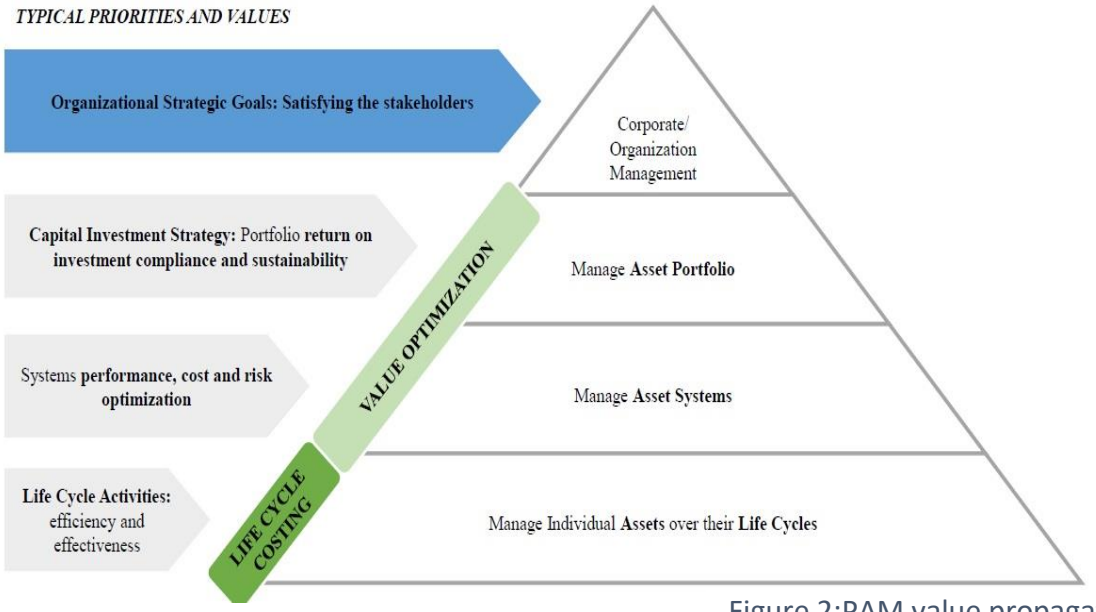


Figure 2:PAM value propagation

1.3. Strategic Asset Information

"You can't manage what you don't measure" - Inherent within any asset management system is the requirement of asset information and feedback systems. As illustrated in figure 3 - asset information (also referred to as asset knowledge enablers), provides the ability to make more informed decisions and take action with regard to strategic management.

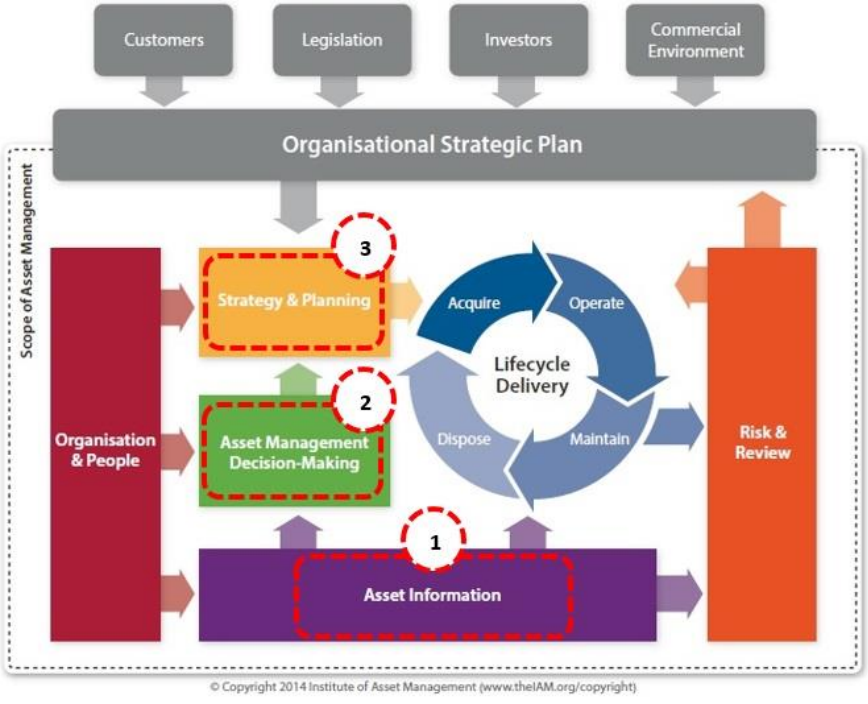


Figure 3: Institute of asset management - Scope of AM

1.4. Smart Asset Management

The scope of AM as illustrated in figure 3, highlights the inter-relations of various aspects in the implementing an AM system. Where these interrelations are often manual processes which require time and energy. The concept of Smart Asset Management (SAM), is aimed at automating certain process by combining the ability of technological inter-operability, between assets and strategic management systems. **SAM systems and devices are tools which allow for the collection of information for asset managers to make more informed decisions to take actions which lead to optimal results.** The influence of, as well as the areas affected by, SAM are numbered in the figure which illustrate the intervention of SAM contributing to the entire AM proses.

2. Research Methodology

This following section investigates the reason as well as processes followed for conducting the study. Where ultimately this research is conducted to fulfil the completion of Master's degree in Engineering Management, completed through the Industrial Engineering Department of Stellenbosch within the Asset Care Research Group.

2.1. Problem statement

According to the World Health Organisation (WHO), health infrastructure technologies are an essential basis for the correct functionality of an effective healthcare system. With respect to technology improvement and developments in asset maintenance systems there is also a definite trend in general technical operations departments utilising technological drivers with respect to monitoring equipment to improve efficiencies, mitigate failure and improve equipment utilisation.

The Aberdeen group is an independent organisation which identifies best practices within asset owning organisations which rely on AM performance strategies to excel within the competitive business environment. Within their research, this organisation has identified the strategic advantages achieved by organisations, referred to as best-in-class organisations, when technology is integrated into asset information feedback as well as incorporating Digital Asset Management (DAM). Aberdeen also measured the best-in-class performance as related to three Key Performance Indicators; 1)Overall Equipment Effectiveness (OEE), 2)operational throughput and 3)low asset downtime. Although these KPI's are identified for a manufacturing environment, these principles can still hold true for assets within the healthcare sector considering patient safety as a non-negotiable factor. Where the WHO recognises the requirement of these KPI's for effective asset management within the healthcare industry.

Considering the qualitative intricacies of this investigation, it was identified that corporate management within technical operations need to be engaged as well as informed with regard to the context in which SAM can be utilised to address efficiencies, potential risks and further improve asset utilisation. As a result of this understanding a case study approach was adopted to portray a common understanding experienced by technical managers operating within various hospitals across Southern Africa within the MCSA group.

The following research question was identified to further address the research study:

Can the existing concepts of PAM be improved by the in-corporation of reliable and accurate real-time asset data, through SAM constructs, to yield asset knowledge enablers which contribute to reducing critical system failures and improving PAM strategic execution?

Further to this research question it was identified that within the MCSA group there is a lack of a specific guideline or procedural framework available for implementing integrated smart asset communication structures to enhance PAM systems.

2.2. Literature Study

Regarding the problem statement identified, in order to address the research question as well as establish a procedural framework for SAM implementation, an investigation was firstly conducted into existing literature. The theoretical framework as well as current operational implementation is a prerequisite in order to investigate and confirm existing methodologies and standards which address the research concept at hand. Within the literature study conducted various organisations include, amongst others; ISO, the British Standards Institute (BSI), the Institute of Asset Management (IAM), WHO, Health Systems Trust (HST), Aberdeen group, as well as various organisations who incorporate SAM concepts with respect to their business value contribution. The feedback from these organisations is extensively deliberated within the literature study section of the master's thesis, however the total feedback has been omitted from this validation to reduce the total required reading, where important aspects have been highlighted in the introduction. The document structure for this thesis is outlined in figure 4.

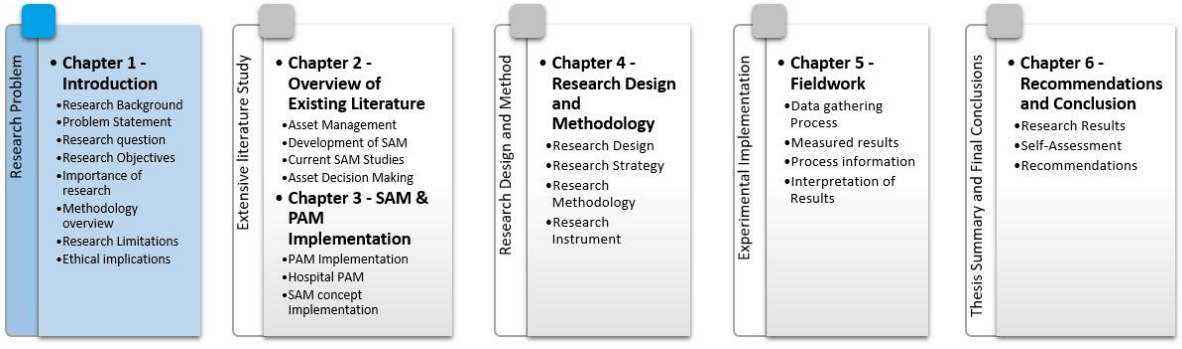


Figure 4:Thesis Document Structure

These identified organisations are used as an industry benchmark regarding the implementation of the concepts related to SAM. Utilising these sources as well as various cited academic authors as a baseline for the proposed research, a research agenda was created to formalise the basic understanding toward the requirements as well as the implementation of SAM concepts.

2.3. Research design and methodology

The basis for any theoretical research is captured in the research design framework as established by well-known author John Creswell concerning research design concepts.

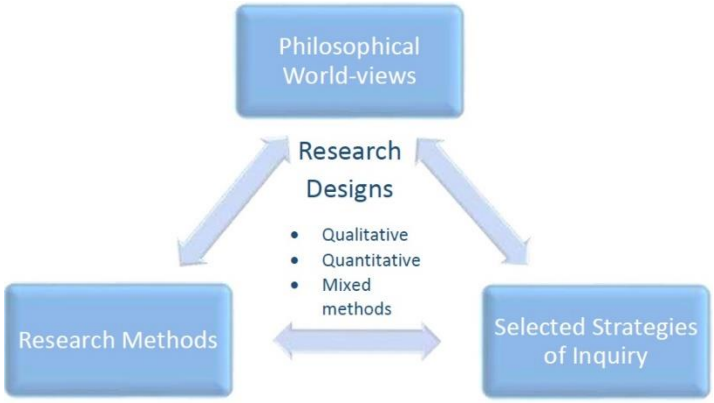


Figure 5: Research Design

This research design illustrates the connections between your primary methods of collecting information, your personal world view which influences the research conducted as well as the basic strategy of inquiry, in other words whether the research is based on statistical facts and figures (quantitative) or verbal feedback interpretations to questionnaires and interviews (qualitative).

The research method followed in this thesis is a qualitative research processes where the method of inquiry is a case study approach, making use of a structured interview process to investigate a specific case, namely the use of SAM principles confined to MCSA. The reasoning behind this case study approach is to allow the researcher the opportunity to collect multiple sources of evidence pertaining to a single case or event which is under investigation. This allows a triangulation method to be implemented in order to verify the information collected. Sources of information within MCSA include the questionnaire sent to technical managers, the Computerised Management Maintenance System (CMMS) i.e. Onkey and/or SAP, PLM policies (technical documentation) and reported hospital occupancy figures.

2.4. Fieldwork

The research design and methodology process elaborated the basic structure of the research which also described the fieldwork or data gathering process to be conducted. The fieldwork process involved a structured interview process conducted with 10 technical managers, where their selection was according to varying hospital size, varying location as well as availability to participate within the research.

This questionnaire was conducted through an online survey with questions leading to both predefined answer selections, as well as open ended questions to fully capture specific responses to certain questions. From this questionnaire, outcomes to be identified was not related to how implementation of SAM is to be considered or established but rather areas appropriate to SAM implementation within the hospital environment. This involved identifying specific departments from an operational and economic point of view as well as assets which were critical to the infrastructural operation of this identified department. Once establishing which assets were the most critical in nature, other aspects for consideration was unavailability due to asset failure as well as reporting structures to capture information relevant to this downtime.

If you require further information regarding which questions were addressed, please to hesitate to contact me for more information or a copy of the physical questionnaire.

2.5. Recommendations and conclusions

From the completed fieldwork is it evident that theatre complexes are the most economically important department within the private hospital environment where specific asset infrastructures are critical to this and various other departments within the hospital. It was also established that specific measurements to theatre unavailability have various system related gaps where adequate records of such failure or unavailability is not always accurately captured. Finally, it was also established that all technical managers consider remote monitoring a viable means to contribute value to maintaining critical asset infrastructures.

Therefore, to address the initial problem statement as well as the information gathered from the fieldwork, a proposed specific MCSA policy pertaining to the implementation of monitoring devices appropriate to SAM methodology is to be created. This policy should incorporate the various aspects of the literature study as well as feedback obtained from the data gathering process. Such a proposed policy has been created and added to this validation procedure, where comments for the implementation of such a document are welcome. In defining an implementation procedure, assets identified as critical are included in this policy where recommendations are made according to which assets require priority monitoring in certain applications. In conjunction to this policy, further involvement from the technical operations department is asserted in order to contribute and guide TM/TS's with respect to remote monitoring strategies which ultimately contribute to improving PAM within the hospital environment to improve utilisation and efficiencies. This implementation strategy is based on sound practises identified from various standards organisations and bench marked ideals.

From this validation procedure, various aspects have been highlighted concerning an identified problem statement, academic procedures followed to address this problem statement and finally reach certain recommendations toward addressing the context of the identified problem statement. Regarding this proses, the culmination of the validation process leads to feedback related to the procedure followed. The validation process is conducted two-fold, in terms of procedural framework and content application. Where the procedural framework relates to the research methodology followed and secondly the content application refers to the proposed implementation process. Questions pertaining to this validation proses are considered in the following section, where answers will be collected verbally during the telephonic feedback session to ensure the entire context has been captured from each response.

3. Questions

3.1. Question pertaining to the research methodology followed

a. Do you agree that an appropriate research methodology was conducted, which is relevant to the topic being investigated? Yes or no, and please give reasons for your answer
b. In your opinion, what are the strong points of the research methodology utilised?
c. In your opinion, what are the weak points of the research methodology utilised?
d. Considering the research methodology which was followed to investigate SAM implementation and identify critical assets within the hospital environment, what is your opinion of the potential of the SAM policy as an objective decision-making tool for assisting MCSA TM/TS's to improve PAM within the hospital environment?
e. Please comment on the architectural aspects of the research design framework, regarding the data gathering methods and specifically the questionnaire.
f. Based on your previous comments, how do you think it is possible to improve the research study?

3.2. Question pertaining to proposed implementation of SAM

a. Considering the proposed MC policy document for the implementation of the concept of SAM, do you find the document to be (yes or no, and please give reasons for your answer):
    i. Required?
    ii. Appropriate to private hospitals?
    iii. Factual in content?
    iv. Usable by the MC group?
b. Do you believe that SAM MC policy document facilitated the decision process in the utilisation of a proposed monitoring requirement? Yes or no, and please give reasons for your answer
b. Would you apply the proposed MC policy document to implement the SAM methodology? Yes or no, and please motivate your answer
c. Do you agree or disagree that the implementation of MC SAM policy would add value within MC and furthermore would this value contribution be appropriate to other related industries?
d. What are the strong points of the proposed SAM implementation?
e. What are the weak points of the proposed SAM implementation?
f. What aspects of the proposed SAM implementation requires improvement?

Appendix B

Ethical Consent

B.1 Mediclinic Consent to Conduct Research

MEDICLINIC

MEDICLINIC OFFICES
STRAND ROAD
STELLENBOSCH
7600

PO BOX 456
STELLENBOSCH
7599

T +27 21 809 6500
F +27 21 809 6756
ETHICS LINE 0800 005 316

www.mediclinic.co.za

10 November 2016

TO WHOM IT MAY CONCERN

I Kevin Poggenpoel (General Manager Technical Operations) do hereby give Charles B. H. Nel, student at Stellenbosch University and employee of Mediclinic, permission to conduct research within Mediclinic Southern Africa concerning his Master's Thesis in Physical Asset Management.

Charles Nel, (student #15055418 ID# 880523 5187 089), will be allowed to conduct research regarding the following elements:

- Send a research questionnaire to the following Mediclinic Technical Managers / Supervisers.

    1. Vergelegen
    2. Midstream
    3. Panorama
    4. Cape Gate
    5. Kimberley
    6. Swakopmund
    7. Durbanville
    8. Victoria
    9. Newcastle
    10. Nelspruit

- Gather information concerning the Technical Operations within the theatre technical infrastructure as well as factors influencing theatre uptime.
- Retrieve feedback concerning theatre equipment failures.
- Gather information illustrating the number of patients admitted to the hospital which utilise the theatre facilities.
- Gather feedback from Technical Operational management at Corporate Office concerning proposed implementation of smart asset management.

Do not hesitate to contact me should you require any additional information.

Kevin D. Poggenpoel
GENERAL MANAGER TECHNICAL OPERATIONS

B.2 University of Stellenbosch Consent Form

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY
WRITTEN CONSENT TO PARTICIPATE IN RESEARCH

TITLE OF RESEARCH PROJECT:	A Case Study for Integrating Smart Asset Management Within Operating Theatres in a Private Healthcare Group to Mitigate Critical System Failure
REFERENCE NUMBER:	**SUHSD004164**
PRINCIPAL INVESTIGATOR:	**Charles Benjamin Hirschowitz Nel**
ADDRESS:	Department of Industrial Engineering, University of Stellenbosch, Private Bag X1, Matieland, 7602, South Africa
CONTACT NUMBER:	078 639 7072
E-MAIL:	Charles.nel@mediclinic.co.za

Dear Participant,

Kindly note that I am a MEng student at the Department of Industrial Engineering at Stellenbosch University, and I would like to invite you to participate in a research project entitled "A Case Study for Integrating Smart Asset Management Within Operating Theatres in a Private Healthcare Group to Mitigate Critical System Failure".

Please take some time to read the information presented here, which will explain the details of this project and contact me if you require further explanation or clarification of any aspect of the study. This study has been approved by the Research Ethics Committee (REC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

1. **INTRODUCTION:**

This research study is related to the development of a research field known as Physical Asset Management (PAM), where international standards organisations, such as the British Standards Institute (BSI) and the International Standards Organisation (ISO), have contributed to creating frameworks for establishing as well as formulating industry best practices for the management of physical assets.

As identified by the World Healthcare Organisation (WHO), an effective medical equipment maintenance program consists of adequate planning, management and implementation where the administration of healthcare technologies are an essential basis for the correct functionality of an effective healthcare system.

2. **PURPOSE:**

This purpose of this research study is related toward exploring the qualitative aspects of enhancing operational and corporate management through incorporating technological communication methods to produce asset knowledge enablers allowing better management decisions to be made. It is within this awareness, that this research study is focused on the value contribution of a newly defined concept, Smart Asset Management (SAM) used to integrate sectors of asset information and using asset communication possibilities to improve the strategic maintenance management of operating theatres within the Mediclinic Southern Africa (MCSA) group. This research is conducted in order to assist with the prevention of critical system failures hence overcoming asset unavailability and also addressing competitive pressures of providing healthcare facilities to practitioners who can be considered customers in choosing to utilise MCSA services.

3. **PROCEDURES:**

The procedure of this study will involve the prospective participant, who will assist by completing an online questionnaire which multiple choice questions and long answers to explain some of these decisions. Therefore individuals involved in the data collection will be the researcher (principal investigator) and participants with the knowledge of asset maintenance within operating theatres. These participants include Technical Managers and Technical Supervisors, from MCSA, responsible for ensuring that equipment / assets pertaining to theatre complexes are in working condition, where preventive and corrective maintenance is applied.

4. **TIME:**

This questionnaire, depending on the participant will take about 30min to complete

5. **RISKS:**

Please take note that no known risks and/or discomforts, inconvenience, psychological stress and stigmatisation are associated with this study. You are also assured that you will not be treated as objects nor be manipulated in any way. If at any point you should experience any discomfort or have any complaints during the questionnaire, you have the right to stop at any time necessary or contact the researcher and supervisor personally. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

6. **BENEFITS:**

No promise can be made that this study will benefit you as an individual, however, your participation will contribute to the gained knowledge and relevance of asset management to the physical asset management industry. If submitted for publication, an acknowledgement will be indicated for the participation of all participants. Unfortunately, you as participant will not receive any payment for participation, but you will receive the researcher's and supervisor's gratitude

7. **CONFIDENTIALITY**

The potential collected research and any other electronic documentation or communication from the participant will be safely stored on a personal computer which is password protected. The information collected will be kept confidential at all times and no third party will be granted permission to be able to access these documents. Upon completion of the study, the original questionnaires will be disposed in a confidential manner. Participant's feedback will also remain anonymous within the dissertation feedback.

8. **RECORDINGS:**

With your permission, this questionnaire will be electronically completed via an e-mail link to an online questionaire, where the researcher will solely have access to the recordings where any communication separate from this questionnaire is welcome and will also be treated with the same conditions as highlighted within this consent participation. This questionnaire will be compared to other responses from participants within the same field, where responses will be further analysed to draw appropriate conclusions.

Any findings post completion of the research would be gladly shared with you if you would be interested and requested to do so. Hence, your personal details, documents and records will be kept confidential for research purposes only. Your identity as participant will only be known to the researcher while you will remain anonymous to the other participants throughout the interviews. Your participation to the findings will be accessible to the researcher, supervisor and examiner solely where no data sharing is envisaged. Also, any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

9. **DATA STORAGE:**

The potential collected research and any other electronic documentation or communication from the participant will be safely stored on a personal computer which is password protected (no third party will be granted permission to be able to access these documents, it will only be accessible to the researcher). Upon completion of the study, the original questionnaires will be disposed in a confidential manner. Participant's feedback will also be anonymous when used within the dissertation, where individual responses will be referred to with generic identifiers not associated to specific participants

If you have any questions or concerns about this research project, please feel free to contact:

Charles B. H. Nel (Principal Investigator) Cell: 078 639 7072 Email:cbhnel@gmail.com / Charles.nel@mediclinic.co.za
Dr. J.L. Jooste (Supervisor) Tel: 021 808 4234 Email: wyhan@sun.ac.za

RIGHTS OF RESEARCH PARTICPANTS: You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché (mfouche@sun.ac.za / 021 808 4622) at the Division for Research Development. You have the right to receive a copy of this Consent form.

If you are willing to participate in this research project, please sign the Declaration of Consent below and returned a signed copy of the declaration via e-mail to the principal investigator.

DECLARATION BY THE PARTICIPANT

As the **participant** I hereby declare that:

- I have read the above information and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.

- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- If the principal investigator feels that it is in my best interest, or if I do not follow the study plan as agreed to, then I may be asked to leave the study before it has finished.
- All issues related to privacy, and the confidentiality and use of the information I provide, have been explained to my satisfaction.

By signing below, I _____ *(name of participant)* agree to take part in this research study,

as conducted by Charles B. H. Nel *(principal investigator).*

_____ _____

Signed at *(place)* **Date**

_____

Signature of Participant

DECLARATION BY THE PRINCIPAL INVESTIGATOR

As the **principal investigator** I hereby declare that the information contained in this document has been thoroughly explained to the participant. I also declare that the participant has been encouraged (and has been given ample time) to ask any questions. In addition I would like to select the following option:

	The conversation with the participant was conducted in a language in which the participant is fluent.
	The conversation with the participant was conducted with the assistance of a translator, and this "Consent Form" is available to the participant in a language in which the participant is fluent.

_____ _____

Signed at *(place)* **Date**

_____

Signature of Principal Investigator

Appendix C

Philosophical Assumptions with Implications for Practice

Table C.1: Philosophical Assumptions with Implications for Practice - *adapted from (McLaughlin, 2003)*

Assumption	*Question*	*Characteristics*	*Implications for Practice (examples)*
Ontological	What is the nature of reality?	Reality is subjective and multiple, as seen by participants in the study.	Researcher uses quotes and themes in words of participants and provides evidence of different perspectives.
Epistemological	What is the relationship between the researcher and that being researched?	Researcher attempts to lessen distance between himself or herself and that being researched.	Researcher collaborates, spends time in field with participants, and becomes an "insider."
Axiological	What is the role of values?	Researcher acknowledges that research is value laden and that biases are present.	Researcher openly discusses values that shape the narrative and includes own interpretation in conjunction with interpretations of participants.
Rhetorical	What is the language of research?	Researcher writes in a literary, informal style using the personal voice and uses qualitative terms and limited definitions.	Researcher uses an engaging style of narrative, may use first-person pronoun, and employs the language of qualitative research.
Methodological	What is the process of research?	Researcher uses inductive logic, studies the topic within its context, and uses an emerging design.	Researcher works with particulars (details) before generalisations, describes in detail the context of the study, and continually revises questions from experiences in the field.

Appendix D

SAM Implementation Procedure

D.1 Proposed Mediclinic Policy

GROUP: **CORPORATE** **TYPE:** **MANUAL** **SUBJECT:** **TECHNICAL OPERATIONS MANAGEMENT SYSTEM Incorporating SMART ASSET MANAGEMENT**	MEDICLINIC

Smart Asset Management - Technical Operations Management Incorporating Remote Monitoring Systems
Doc No: SAMMAN Effective Date: Draft Review Date: Draft

TABLE OF CONTENTS

ACRONYMS

BMS	BUILDING MANAGEMENT SYSTEM
ISO	INTERNATIONAL STANDARDS ORGANISATION
KPI	KEY PERFORMANCE INDICATOR
MCSA	MEDICLINIC SOUTHERN AFRICA
MRSF	MASTER RECORD SCADA FILE
MSI	MAINTENANCE SIGNIFICANT ITEM
PAR	PREVENTIVE ACTION REQUEST
PLC	ROGRAMMABLE LOGIC CONTROLLER
QMS	QUALITY MANAGEMENT SYSTEM
RTOM	REGIONAL TECHNICAL OPERATIONS MANAGER
SAM	SMART ASSET MANAGEMENT
SCADA	SUPERVISORY CONTROL AND DATA AQUISITION
TM	TECHNICAL MANAGER
TS	TECHNICAL SUPERVISOR
WDSF	WORKING DOCUMENT SCADA FOLDER

1. PURPOSE

This document establishes general operating principles for the implementation of Mediclinic Southern Africa (MCSA) procedures regarding the management of remote monitoring information through SCADA software. The purpose of this manual is also to assist with not only the implementation of SCADA but more so to create an awareness for the user to apply technological drivers in conjunction with sound management principles. Hence the terminology Smart Asset Management (SAM) is utilised as a way of thinking, where the identified tools are used to provide value within a predefined clear strategy which is implemented to ensure action is derived from the information collected.

2. SCOPE

This manual applies to Technical Managers (TM) and Technical Supervisors (TS) implementing SCADA within their hospital as well as parties involved in the management of a hospital's critical performance indicator's pertaining to the technical operations.

3. PARENT DOCUMENT

TECOPSMNGMAN - TECHNICAL OPERATIONS MANAGEMENT SYSTEM Incorporating PLANNED MAINTENANCE

MAINTENANCE PREAMBLE

4. RESPONSIBILITY

It is the responsibility of the TM / TS to ensure that the correct procedure is utilised when implementing a SCADA system, where the objective is not to measure as much information as possible, but rather to implement these measurements within a strategic plan. Before SCADA is implemented, the design and objectives of the system need to be considered with respect to the required outcomes. SCADA can be utilised to measure specific information instantaneously, or create an instantaneous notification compared to periodic measurements utilised within a PLM check, **however the implementation of SCADA cannot replace the guidelines as set forth in the TECOPSMNGMAN and the MAINTENANCE PREAMBLE**. SCADA can never replace the many benefits of a daily PLM check, where the general look and feel of a plant as described in the TECOPSMNGMAN remains a necessity.

Each MCSA hospital TM / TS is responsible to:

- Implement the relevant procedures addressed in this manual in their respective hospital;
- Participate in relevant programmes and activities specified in this manual.

The technical operations management team are responsible to:

- Assist hospital management with the implementation of this manual on departmental level;
- Ensure that the management system requirements specified in this manual are implemented and maintained;
- Report the performance of the technical operations management system and implement improvement actions.

5. PROCEDURE

5.1. SMART ASSET MANAGEMENT

SAM is a concept related to the management as well as maintenance of physical assets encompassing the use of technological themes; such a SCADA, PLC's, BMS controllers, etc. as tools to make more informed decisions with respect to managing infrastructure efficiencies. These tools should assist TM / TS in conjunction with MCSA planned maintenance policies to address Quality Management Systems (QMS) as identified by ISO business systems. ISO 9001:2015 is a QMS certification where the fundamental approach is based on a quality circle approach as defined by using a Plan Do Check Act (PDCA) cycle. This continuous improvement cycle in relation to SAM is depicted by the image below.

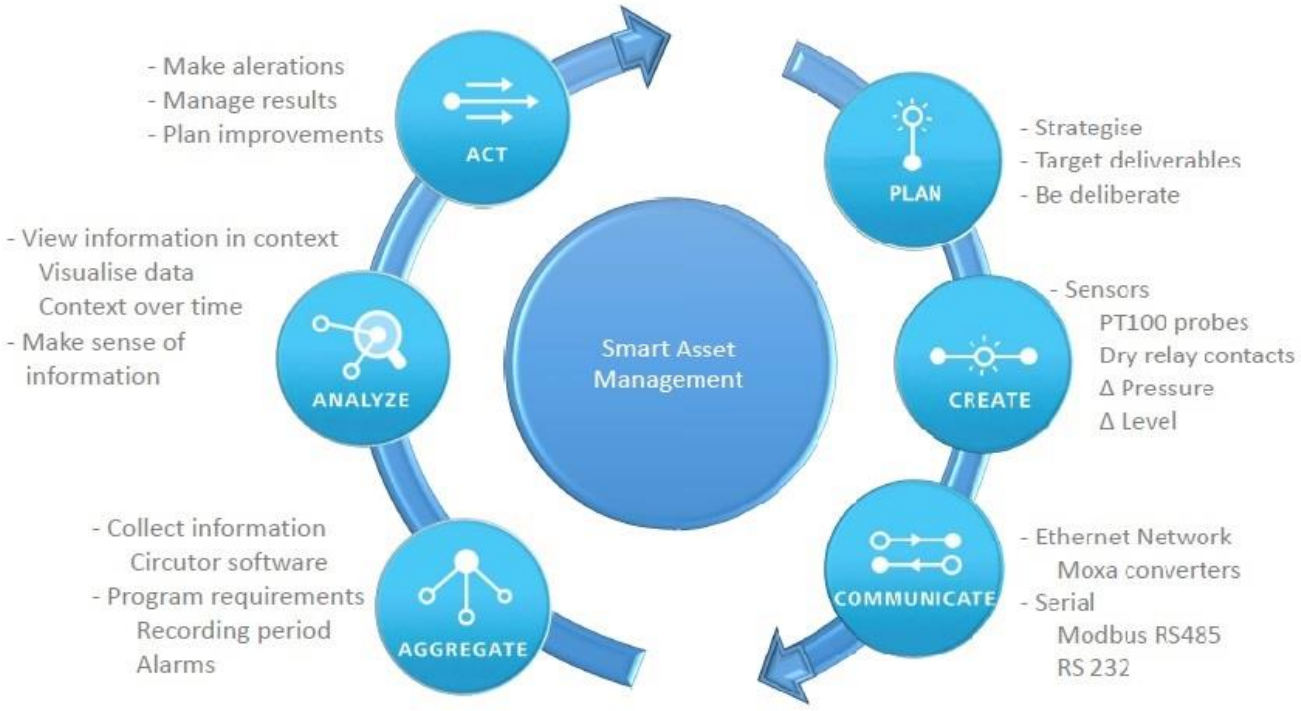


Figure 1:SAM continuous improvement cycle

5.2. SCOPE OF THE SMART ASSET MANAGEMENT SYSTEM

The scope of SAM implementation is concerned with defined critical MCSA assets, plant and equipment which are associated to the operation and infrastructure maintenance utilised within private hospitals. The requirements of this system need to be carefully defined with respect to the importance of the asset being monitored, where the nature of SAM implementation is defined by the following concerns:

- Recording the failure of a critical asset, or asset system.
- Recording the usage or operational runtime of an asset or asset system
- Recording the consumption of resources through a metered reading
- Recording parameters defined with the successful operation of the asset or asset system

It is recommended that asset infrastructure systems associated to Category #1 – Life support and Category #2 – Strategic maintenance are categorically targeted within the SAM scope where example systems are discussed in chapter 5.4.3.

5.3. IMPLEMENTATION OF THE SMART ASSET MANAGEMENT SYSTEM

The implementation of SAM within MCSA is defined by the information value loop as depicted in figure 1. This cycle is concerned with the procedure to ensure that defined critical equipment, plant, building and services are monitored to assist in identifying critical failures as well as measure efficient use of resources and utilisation in the most cost effective way. Furthermore, applicable procedures are to be created and appropriately actioned from the information collected through SCADA. The output of the information collected is an actionable response to address the data collected, as illustrated by figure 2.

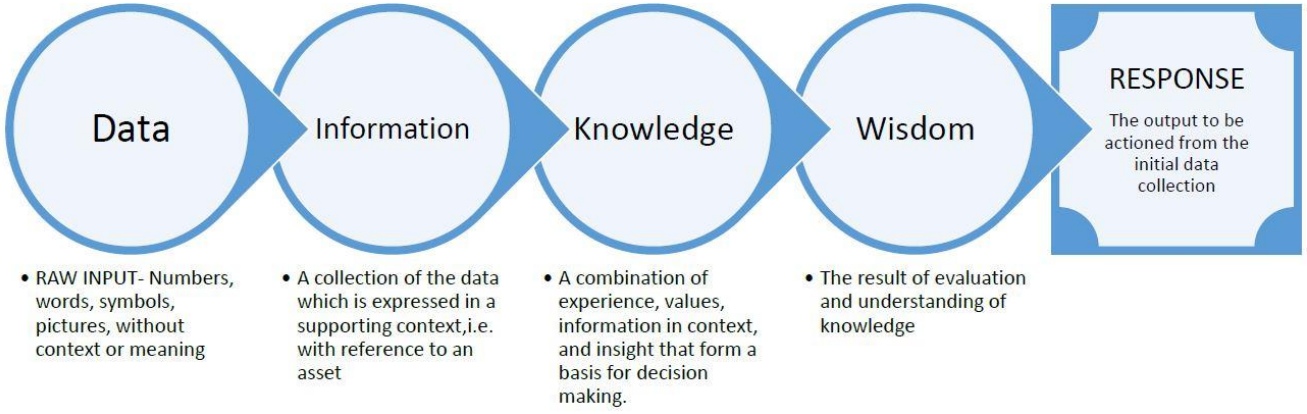


Figure 2: Progression of data to actionable output

The SAM implementation of this procedure is subdivided into the six steps as illustrated by figure 1, which will be further elaborated in the following sub sections.

5.3.1. Plan

The initial step towards implementing a SAM system is concerned not with “how” but rather “why”. “Why are you implementing the system”, what is the desired goals to be achieved. The initial planning phase must identify and document goals, objectives and targets in line with MCSA goals. Part of the planning process must be a programme to meet these identified objectives with targets in a process of continuous improvement. All equipment must be identified for the purpose of setting up a specific measurable output, where this output should equate to an actionable response. A baseline concerning the needs of the hospital should also be fully understood where focus areas, priority, Maintenance Significant Items (MSI) should be considered.

An inclusion plan is required which specifies a list of items that have been identified as a priority to begin with. Where this priority is based on the following:

- Category #1 Life support infrastructure equipment – e.g. ELRET, GAM, LIM;
- Any equipment or service having an adverse risk implication – e.g. HWR, AHU;
- Items that will have a significant impact on the service delivered - e.g. COMSIG;
- As the SAM plan matures and resources develop, more items can be included in the priority list concerned with improving resource utilisation efficiencies as well as the prevention of critical system failures.

5.3.2. Create

Once the deliverables have been established, the next stage toward implementing a SAM system is with respect to creating the basic infrastructure required to support the identified goals. It is important to note the communication infrastructure between the sensor and the

monitoring devices. Some of the basic building blocks for this infrastructure are identified as follows;

- **Sensors** – PT 100 probes, analogue level sensors, relay outputs, meter pulses, power meters, vibration sensors etc
- **Communication infrastructure** – Ethernet cables, Sensor cables, communication cables, network switches, etc.
- **Media converters** – Ethernet to Digital Input/ Output (DIO), PLC's, BMS controllers, Ethernet to RS485/RS232 converters, Lovato generator controllers, etc.
- **Monitoring devices** – Circutor SCADA software, Desktop PC, Visualisation screen, etc.

For an example, refer to the table below to see how these elements are interconnected

Goal	**Sensor**	**Comms Infra.**	**Media converter**	**Comms Infra.**	**Monitoring device**
Measure water mains back up water level	Water level sensor with 0-10vDC or 4 -20ma Output	Mylar 4 core 0.22mm cable from sensor to media converter *	Moxa ioLogik E1242	Ethernet network cable (cat6e) to network switch	Circutor SCADA software on desktop PC connected to MC network
Measure ELRET mains KWh / Max KVa	Power meter (CVM_C10) + Current Transformers (CT)	Mylar 4 core 0.22mm cable from sensor to media converter *	Moxa Mgate MB3170	Ethernet network cable (cat6e) to network switch	Circutor SCADA software on desktop PC connected to MC network
Measure HWR output	PT100 probes	Mylar 4 core 0.22mm cable from sensor to media converter *	Moxa ioLogik E1260	Ethernet network cable (cat6e) to network switch	Circutor SCADA software on desktop PC connected to MC network

*Mylar cable has an aluminium sheath assisting with prevention of external noise inference

As a result of this required communication infrastructure, it is important to plan where these devices should be located within the hospital. The media converters and monitoring devices also need to be housed in an isolated environment (a separate DB) with a reliable power supply, where unwanted user access is to be restricted. The electrical protection of these devices concerning field wiring should also be taken into consideration, refer to **H:\depts\TECHNICA\\Data & Statistics & Research\Scada Academy** for further recommendations. Furthermore, planning the location can maximise the number of assets which can be connected to a single media converter, and possibly minimise the cable length required between devices. An example of such a plan is illustrated in figure 3. This layout diagram is based on a hospital plan where significant items have been identified within the SAM system. This file as well as the goals and aims for each asset is contained within the Master Document SCADA File (MDSF) which outlines the proposed connections and expected actions for improving the SAM system. The documented folder allows all information to be centrally housed and accessible for future reference.

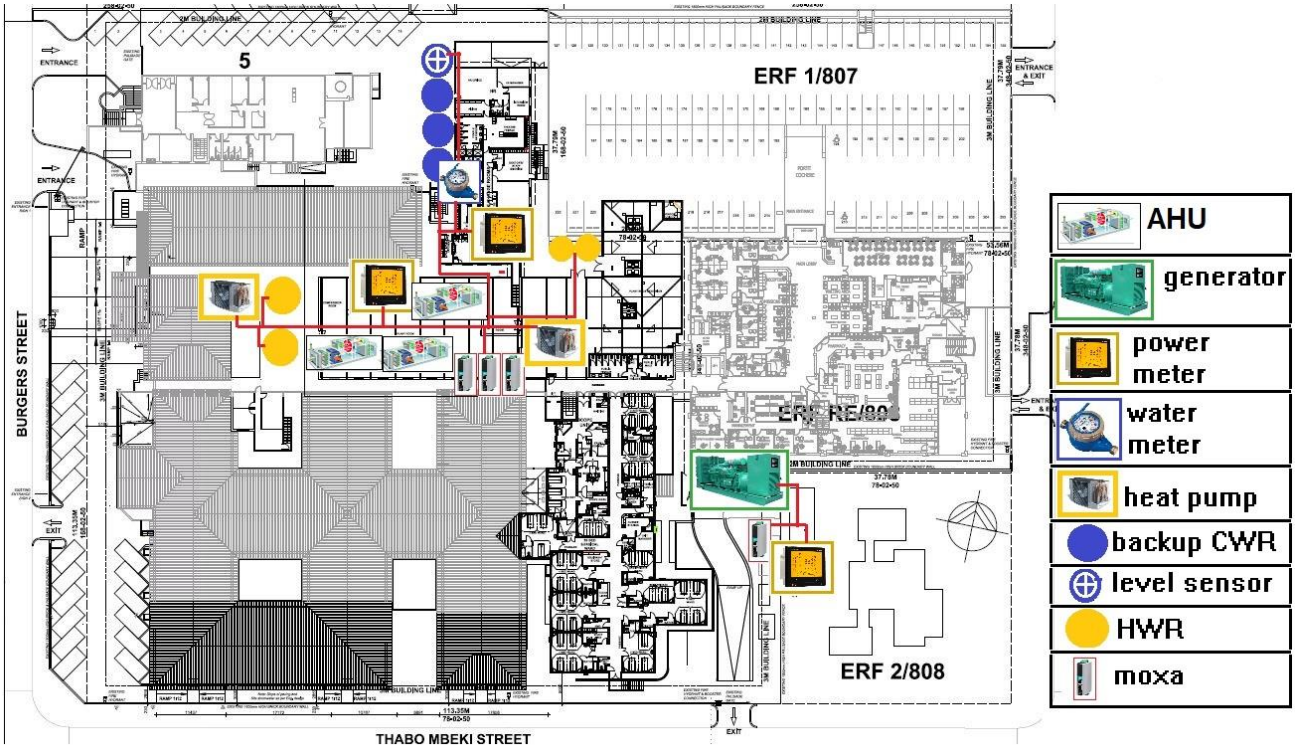


Figure 3: example layout of a SAM system

5.3.3. Communicate

Within the MDSF should also be the Master Record Scada File (MRSF), this excel file is defined as the central document housing information concerning the communication aspects of the SAM system, where the template document is situated within the **H:\depts\TECHNICA\\Data & Statistics & Research\Scada Academy\Software\Naming Convention**. Within this file, the naming and address convention is defined for SCADA equipment, including IP addresses of the relevant SAM equipment namely media converters, PLC's etc. The allocation of these addresses is supplied directly from the infrastructure department, through the Electrical Technical Specialist, who also keeps a record of the dedicated IT equipment related to SCADA equipment. This list has been allocated from the ICT department, which allows the equipment to have **dedicated addresses** which are not to be interfered with or changed.

Please note that the MCSA ICT network is interconnected, where access to IT equipment such as media converters is accessible on the network to all hospitals. Therefore, it is important to standardise on the conventions discussed in this document so as to avoid conflicting operations within the group.

This help file further assists with the available conventions and devices required in the creation of the SAM system as well as locating information of the SAM system within a central location. This operations system documentation is required to standardise the relevant information concerning the location of devices as well the creation of sensor naming conventions which are connected to the respective media converters. An example screen shot of the MRSF is displayed in figure 4 where is it evident from this example how the equipment should be labelled.

NAME			DESCRIPTION		CONVERTER ADDRESS	LEGEND	
NAMING CONENTIC	CONVERTER NUMBER	MODEL	BRAND	MODEL	ALLOCATED IP ADDRESS	CODE	DESCRIPTION
Hospital	Converter	Model/Type				CNV001_	CONVERTER 001
						N5110	MOXA NPORT 5110 SERIAL SERVER
BAR_	CNV001_	N5110	Moxa_	N5110	EG 10.125.150.31	MB3170	MOXA MB3170 CONVERTER
BFN_	CNV002_	MB3170	Circutor_	MB3170		E1210	MOXA I/O DEVICE
BRT_	CNV003_	E1210	Lovato_	E1210		E1212	MOXA I/O DEVICE
CGT_	CNV004_	E1212		E1212		E1240	MOXA I/O DEVICE
CON_	CNV005_	E1240		E1240		E1242	MOXA I/O DEVICE
CPT_	CNV006_	E1242		E1242		E1260	MOXA TEMPERATURE I/O DEVICE
DUR_	CNV007_	E1260		E1260		RGK800	LOVATO GENSET CONTROLLER
EML_	CNV008_	UPS1		RGK800		UPS1	UNINTERRUPTIBLE POWER SUPPLY 1
ERM_	CNV009_	GEN1				GEN1	GENERATOR 1
GEO_	CNV010_	TCP1RS					
GNV_	CNV011_	TCP2RS					
GRP_	CNV012_						
GYN_	CNV013_						
HER_	CNV014_						
HGL_	CNV015_						
HVD_	CNV016_						
HWK_	CNV017_						

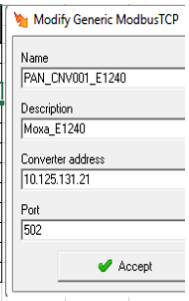


Figure 4: Master Record SCADA File

This communication across the MCSA network also allows the information to be accessible from anywhere within the network, where an internet browser such as Internet Explorer, Google Chrome or Firefox on any MCSA networked device can be used to display the SCADA information.

5.3.4. Aggregate

The aggregation or collection of information is based on the singular data elements defined within the planning and creation phase. These single elements of information need to be programmed per relevant time periods of measurement to be recorded on the SCADA database. Within the MRSF is the naming convention of these data elements that need to be programmed on the SCADA monitoring software. For further reference on how to complete the programming, refer to the **H:\depts\TECHNICA\\Data & Statistics & Research\Scada Academy** folder where example illustrations have been created. Furthermore, refer to figure 5 and 6 as an example of the naming convention of these devices and data points which are to be captured.

Name				Description	LEGEND	
MEASUREMENT	CONVERTER NUMBER	EQUIPMENT	EQUIPMENT NUMBE	Eg Pressure Vacuum Pump Plan	CODE	DESCRIPTION
	SAME AS CONVERTER NUMBER				EPH	POWER
EPH_	001_	CPR_	000 (only for total of)		PRS	PRESSURE
PRS_	002_	EKI_	001		TMP	TEMPERATURE
TMP_	003_	HPM_	002		FLO	FLOW
FLO_	004_	AHU_	003		STA	STATUS
STA_	005_	VAC_	004		IRA	IRRADIANCE
IRA_	006_	MBO_	005		RPM	REVOLUTIONS PER MINUTE
RPM_	007_	HWT_	006		VOL	VOLUME
VOL_	008_	EWT_	007		CND	CONDITION
CND_	009_	ACL_	008		DAC	DAILY CHECK
DAC_		UPS_	009		NOI	NOISE
NOI_		GEN_			HUD	HUMIDITY
HUD_		THS_			CPR	COMPRESSOR
AMB_		CWR_			ILH	INLINE HEATER
VAR_		SWH_			HPM	HEATPUMP UNIT
		PIN_			AHU	AIR HANDLING UNIT
		DRM_			VAC	VACUUM PUMP
		LAU_			MBO	BULK TANK
		KTC_			HWT	HOT WATER TANK
		MFD			EWT	EMERGENCY WATER TANK

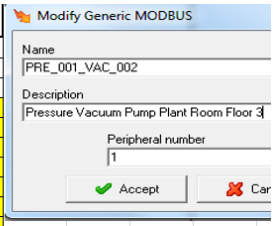
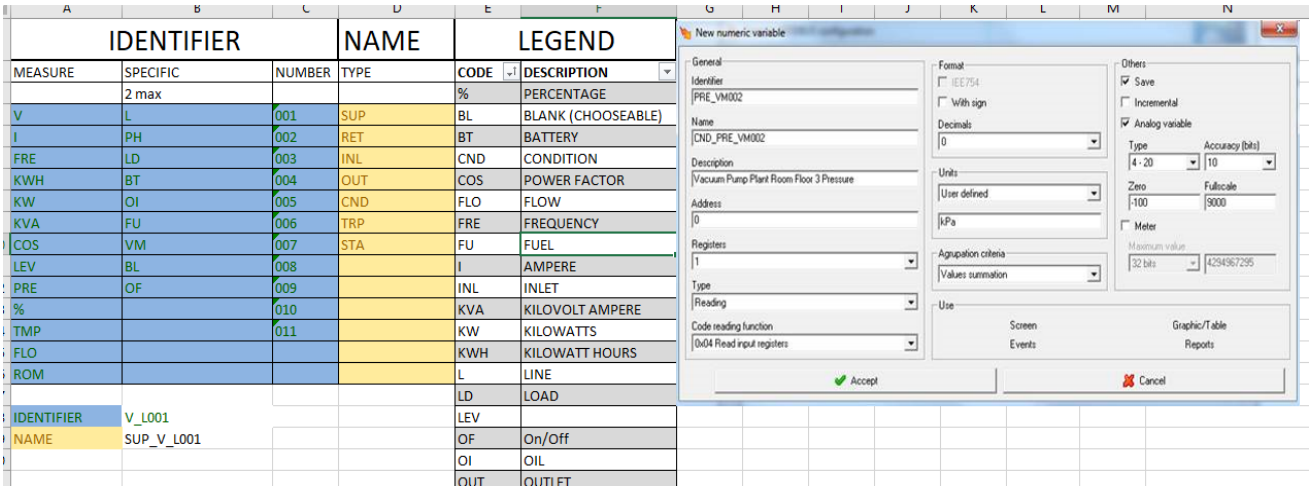


Figure 5: Naming convention of devices



IDENTIFIER			NAME	LEGEND	
MEASURE	SPECIFIC	NUMBER	TYPE	CODE	DESCRIPTION
	2 max			%	PERCENTAGE
V	L	001	SUP	BL	BLANK (CHOOSEABLE)
I	PH	002	RET	BT	BATTERY
FRE	LD	003	INL	CND	CONDITION
KWH	BT	004	OUT	COS	POWER FACTOR
KW	OI	005	CND	FLO	FLOW
KVA	FU	006	TRP	FRE	FREQUENCY
COS	VM	007	STA	FU	FUEL
LEV	BL	008		I	AMPERE
PRE	OF	009		INL	INLET
%		010		KVA	KILOVOLT AMPERE
TMP		011		KW	KILOWATTS
FLO				KWH	KILOWATT HOURS
ROM				L	LINE
				LD	LOAD
IDENTIFIER	V_L001			LEV	
NAME	SUP_V_L001			OF	On/Off
				OI	OIL
				OUT	OUTLET

Figure 6: Naming convention of data points

5.3.5. Analyse

To analyse the data aggregated, the information needs to visualised in a manner that it can be further interpreted over a certain time period. The information is also to be incorporated with knowledge of back ground events to unravel the physical numbers into useable knowledge which can be further utilised into an actionable response. The visualised information received should also be compared with the relevant goals and objectives set forth in the planning phase to confirm whether any processes require change or intervention. Example figures illustrating the raw information gathered from SCADA are illustrated in figure 7 and figure 8.

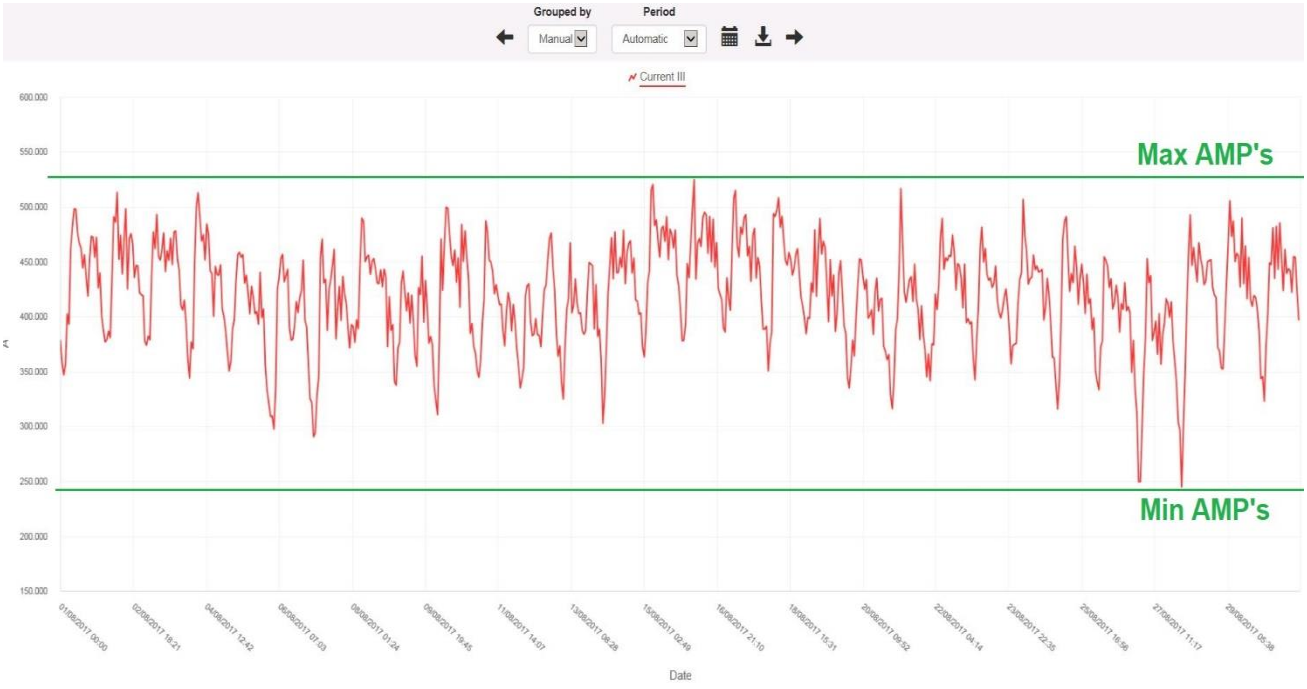


Figure 7: Example waveform of the Maximum current usage

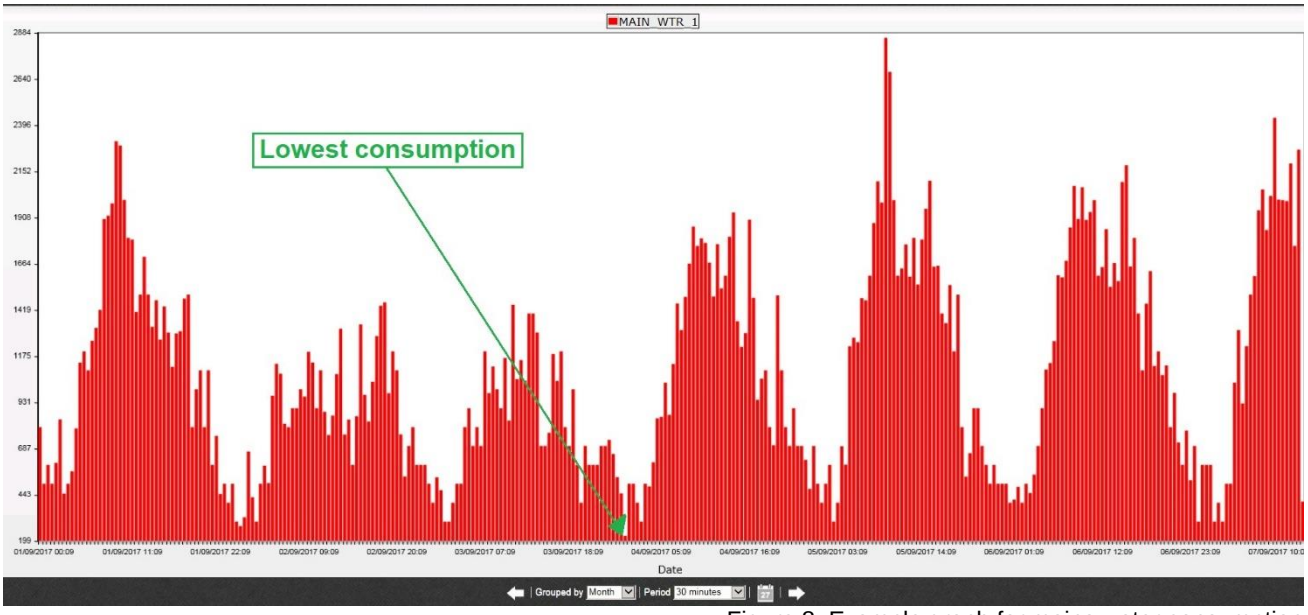


Figure 8: Example graph for mains water consumption

From this analyses, further discretion should be asserted to execute or ascertain the correct procedure to be followed in addressing the issue detected. For example, figure 7 and 8 illustrate some of the basic considerations when interpreting the specific information such as; what is the average consumption, how can the peaks be interpreted, what is the lowest consumption possible etc.

5.3.6. Act

The final factor in the SAM implementation is the most important, where the output of this improvement system needs to be an actionable response to the collected information “you cannot manage what you don’t measure”. Once the information has been visualised with respect to time and compared to further background knowledge, this information should lead to an appropriate response. Apart from capturing the information and being able to visualise it, this information should also be available and visible to a variety of members within the technical department, where a reliance on one person to react to the SAM should be avoided. It is prescribed that a means of alerting the technical team needs to be addressed in order to create awareness regarding measurements which are outside of the expected boundaries. These alarms can be programmed into SCADA where physical alarm alerts can be set to bring about predefined actions as part of the initial planning phase.

5.4. OPERATIONAL CONTROL

It is the responsibility of TM /TS to ensure that SCADA remains a useful tool where the system should be kept functional at all times and add value to the department where all staff members should be in involved. Part of this involvement regards general training where the value add of the SAM system needs to be explained.

It is important to note that the information collected through SCADA becomes useless when not correctly utilised in a continual improvement plan. This information needs to be constantly revised to ensure that information gathered remains useful and applicable to the hospital improvement strategy.

5.4.1. Training, awareness and competence

SCADA cannot replace existing PLM schedules where training and awareness regarding the operation of plant equipment is required to address system failure which can be improved by deriving more information through SCADA.

Part of the process of implementing a SAM system is to clearly identify the work load and roles of technical staff members with regard to the system maintenance as well as additional efficiency ventures to be attempted. Therefore, regarding the training, awareness and competence of staff is to be identified to take part within the SAM system where the following aspects are considered;

- Train staff regarding the reaction protocol for identified alarms / alerts generated by the SCADA system
- Train all members involved regarding the layout and general operation of the system
- Allocate a routine time to visualise acceptable operating procedures
- List all the planned response procedures regarding activation of alarms
- Decide on the short comings with regards to resources and skills
- Develop a skills plan to close the gap
- Measure results against the available resources and usage of similar sized hospitals

Assistance to comply with the above can be obtained from the Regional Technical Operations Manager and training support from head office. It may be necessary to relook at the MSI priority list and adjust according to available resources ensuring that the criteria are correctly applied.

5.4.2. Security of the system

Whilst implementing any SAM system within the hospital environment, a continual awareness regarding the safe operation of the system should be considered in terms of physical safety and protection, as well as software security. Although certain applications are controlled by the IT department in terms of protection against viruses and ransomware, external control to assets should be avoided where existing systems implemented by external contractors should access controlled. User access to such systems is to be restricted to personal with correct training, where TM/TS should administer this process. Concerning general electrical wiring safety, MC standards and specifications apply.

5.4.3. Checking operationality of the system

Systems need to be implemented to confirm that the SAM system remains operational, where system checks need to be implemented to confirm information remains relevant and available.

5.4.4. Suggested monitoring and measurement

An example list of items has been identified which require priority monitoring preference due to the critical nature effecting essential assets of theatres and ICU's. These items have a strong influence on the infrastructure supporting the hospital where these assets are in no order of preference and additional items may be also considered.

- Generator power supply
- Uninterrupted power supply (UPS)
- GAM – Vacuum / Oxygen / Compressed Air
- Line insulation monitoring device
- Isolation transformer
- Air handling unit / climate control
- Laminar air flow

- Water supply
- Autoclaves
- Operating lights
- HWR
- COMSIG

5.4.5. Records and back up data

Back up and records of recorded information should be electronically created through the assistance of service desk support. SCADA records information from set points to a predefined located on the monitoring desktop PC, therefore for the sake of redundancy it is advised that important information regarding the system set up and information collected be stored on a secondary local sever to as to mitigate the risk of losing collected historic data.

APPENDIX A: APPLYING FUNDAMENTAL PRINCIPLES

(This is based on the Maintenance Preamble as written by Brian Woolls-King and approved by Steve Drinkrow in 1998)

To ensure maximum efficiency with minimum down time and cost in a hospital environment in and outside the plant room the following basic principles apply:

- **Inspection** forms the foundation of good maintenance. Its purpose is to anticipate trouble and faults before they occur.
- Inspection should include the making notes of any changes in the plant and equipment, i.e. **visible**, **audible** and **tactile**. Any changes in the normal state of the plant room should also be noted, no matter how trivial.
- One should look for such things as changes in noise levels (up or down), **new noises, and changes in vibration, temperature variations and new accumulation of dirt.**
- **Regular** lubrication should be carried out to ensure the maximum life from equipment. Always ensure that the **correct lubricant** is used, and that it is suitable for the temperatures and loads it is subjected to. **Never** use **old lubricants** from drained gearboxes, even for general purpose lubrication. Oil and grease **sparingly**, as over oiling or greasing can lead to overheating and damaged seals.
- With constant usage, tolerances are bound to vary outside their normal limits, i.e. belts stretch, bearings wear, springs weaken, etc. It is therefore necessary to **make periodic adjustments**.
- Log sheets are to be comprehensively filled in to monitor plant trends and parameters as well as predict plant failure and deviations from set points.
- **Good maintenance** can only prevail in **clean conditions**. **All** plant equipment and the areas in which they are housed should be kept clean. **No** accumulation of dirt should be allowed on surfaces, both **seen and unseen**.
- The purpose of periodic testing is to ensure that plant which is needed under emergency conditions is 100% functional.
- The purpose of testing safety interlocks such as flow and pressure switches, is to ensure that its protection systems on operational plant function correctly to prevent unnecessary repair cost and down time.
- Regular scheduled inspections of an area should be undertaken together with the unit manager or department head. (see point 5.5.5.1 above) These can form part of the management inspection under “Red Flag”. Each area in the hospital, excluding consulting rooms, must be inspected on a quarterly basis.

GLOSSARY

Category of maintenance implementation

Specific maintenance policies are applicable for each piece of equipment, plant, building or service and is detailed as follows:

Category #1 – Life support: all the equipment, plant, or service where a failure would create a risk to the patients' life whether directly or indirectly.
Maintained according to the manufacturers instruction by the agent or an authorised representative or a person appointed by MCSA.

Category #2 – Strategic: all the equipment, plant, building or service that a failure would cause gross inconvenience to our clients, have a large negative financial impact on our business or lower the quality of service we provide.
Maintained according to MCSA policy in house by our staff, the agent or a contractor appointed by MCSA.

Category #3 – General: All equipment, plant, building or service not falling in the above categories. Failure of this equipment still has an overall effect on the service provided.
Maintained according to MCSA policy in house by our staff, the agent or a contractor appointed by MCSA.

The maintenance of Category #1 equipment, plant or service is a non-negotiable and must be carried out when due. All other equipment where there are legal compliance requirements, such as lift inspections, pressure vessel testing, adverse risk implications (infection control), etc. are also non-negotiable and must be carried out when due. Reliability Centred Maintenance (RCM) can be applied for the remainder of Category #2 and #3

Communication

A universal platform allowing the exchange of information, where the exchange medium is known to both sender and receiver

Continual Improvement

Process of enhancing the planned maintenance management system to achieve improvements in overall performance in line with the organisation’s policy

Document Control

Procedure for ensuring effective management of procedures and other system documents

Inspection

It is an assessment of the condition or performance of a piece of equipment or plant. If the assessment identifies the need for an intervention this then becomes a service. This can be called a PIP (Performance Inspection Procedure).

ISO 9000 and ISO 9001

It is a widely accepted official International Standard for Quality Management Systems. ISO9000 is a structured approach designed to manage and control the activities of an organisation and its impact on the wider environment and to focus on client relations in a **cost effective** manner. This is primarily done through the institution of a quality policy, the identification of risks and the establishment of a management programme. A Total Quality Management (TQM) approach ensures that certain standards are met to nullify or reduce the impact of the identified risks.

ISO 9001 is the only standard within the ISO 9000 family that an organisation can become certified against, because it is the standard that defines the requirements of having a Quality Management System. Although MCSA is not certified within this standard, some of the operating principles are followed to ensure a more efficient qualitative process is utilised with respect to PLM. MCSA follows the ISO 9000 and ISO 14001 systems with regard to structure and certain other fundamental rules and believe in a continuous improvement process with regard to all activities.

The King II report recognises the need for organisations to develop a culture of good corporate governance and to act in a sustainable manner, including commitment to its values and to the triple bottom line - economical, social and environmental responsibilities

Master Document SCADA File (MDSF)

A file containing the required naming conventions for specific data points as well as record of the address for the IT equipment used.

Monitoring and Measurement

The measures used to track progression of departmental performance, the achievement of objectives and targets, legislative compliance and the effectiveness of the PLM and associated controls

Organisation

A company, corporation, firm, enterprise, authority or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration

Procedure

A specific way to carry out an activity or process

Regional Technical Operations Manager (RTOM)

This is the person at regional level responsible to ensure the system functions. Irrespectively of other responsibilities, he shall have defined roles, responsibilities and authority for:

- Ensuring that the technical operations management system requirements are established, implemented and maintained within the regions hospitals, in accordance

with the policy

- Reporting on the performance of the planned maintenance management system to regional operations management for comment and as a basis for improvement of the technical operations and PLM systems

Strategic Plan

A documented plan to ensure that MCSA and departmental objectives are met. This could include a SWOT analysis to identify Strengths, Weaknesses, Threats and Opportunities

Test

It is measuring a piece of equipment or plant against set parameters and ensuring that the said equipment or plant functions according to design. Such test is usually documented or included in a service report.

Technical Manager / Supervisor (TM)

This is the person at hospital level responsible to ensure the system functions. Irrespectively of other responsibilities, he shall have defined roles, responsibilities and authority for

- Ensuring that planned maintenance management system requirements are established, implemented and maintained within the hospital, in accordance with the policy
- Reporting on the performance of the planned maintenance management system to hospital top management for review and as a basis for improvement of the PLM

Working Document SCADA Folder (WDSF)

A folder containing all the documents needed for the technical staff member to carry out his assigned duties. Normally hard copy. The documents are PLM year planner or dues lists, procedures, record sheets, and relevant documents to assigned duties including details of strategic area checks. Photocopies of equipment manual pages could also be included to assist

Appendix E

Transcribed heterogeneous interview feedback

The following three sections contain the transcribed feedback from the heterogeneous interviews, where the researcher is referred to as RE and the candidates answers to the questions are referenced to numerically as C1,C2 and C3.

E.1 Candidate 1

Introductory questions

RE Do you agree to take part in this study where our conversation will be recorded for research purposes?

C1 Absolutely

RE Have you read through the supporting documents and do you have any questions or queries?

C1 Yes, we have discussed some queries
aside *Initial discussion before interview was related to intention of research, where candidate's viewpoint was related to the possibility of investigating building monitoring and efficiency compared to specifically monitoring only operating theatres. Candidate was informed that building monitoring and efficiency was outside the scope of this research study. To ensure focus within the private healthcare environment, only assets supporting theatre infrastructure was considered.*

Question pertaining to the research methodology followed

RE Do you agree that an appropriate research methodology was conducted, which is relevant to the topic being investigated? Yes or no, and please give reasons for your answer

C1 Yes, um what I did see was your introduction and methodologies used and also referred to John Creswell and research sound concepts which I took you have implemented within this research.

RE In your opinion, what are the strong points of the research methodology utilised?

C1 I think that you, went and questioned the people at the cold face, the technical manager with actual relevant, experiences from them with regard to what they faced on daily basis, so I think with conducting the research with them, obviously you were able to add a lot of value because that is actually what is occurring on the ground level.

RE In your opinion, what are the weak points of the research methodology utilised?

C1 To be honest with you, I am not in a position to comment on that because I don't actually know with regards to Mr Cresswell (*reference to John Cresswell's research methodology*) and what he said what shouldn't be done. So to be frank with you I think that your mentor, he's the guy that does ((*pause*)) assists you with your masters, (*researcher refers to study leader*), ja your study leader, he is in the position to actually answer that.

RE Considering the research methodology which was followed to investigate SAM implementation and identify critical assets within the hospital environment, what is your opinion of the potential of the SAM policy as an objective decision-making tool for assisting MCSA TM/TS's to improve PAM within the hospital environment?

C1 Oh that's large, I think that its an area that Mediclinic needs (*emphasis on word - needs*) to become ((*pause*)), needs to get themselves in a position where prior to the expensive process of, I put the whole week aside for and then in two weeks, have to go through the capital budget review that we have more information available prior to that process, of the actual expenditure on those assets, and it's efficiencies. What we are finding, and I have been involved with few of them, that we are looking at replacing large capital equipment

purely based on the efficiency or inefficiency of that equipment. So it is large and it certainly could do with a lot of refinement and I think linked to SAP (*reference to CMMS*), that is where the real value could be unlocked.

RE Please comment on the architectural aspects of the research design framework, regarding the data gathering methods and specifically the questionnaire.

C1 Again I think that my previous answer in terms of your study leader applies. But ((pause)) I thought what I have read and the document that I have worked through and that you developed, covers and is very thorough and comprehensive. There is something that ((pause)) the way you versed is obviously very achievable, and I think that all of the hospitals within Mediclinic are busy with a lot of SCADA implementation. (*Candidate goes on to refer elaborate an example within a specific hospital in his region, where the application of data monitoring revealed positive results. The information which was gathered from this example was able to substantiate SCADA implementation due to the availability of information which was previously not accessible. Therefore arguments could be based on facts and figures instead of presumptions. Candidate finishes of by affirming the requirement of implementing monitoring systems to achieve specific information*)

RE Based on your previous comments, how do you think it is possible to improve the research study?

C1 On this particular topic, as we previously discussed I honestly don't think there much more that can be done, I mean it's a case of now implementing what is encapsulated and then getting the value back out of what was discussed and obviously there are, building on this, there are other aspects that would further be able to get on this physical asset management going forward and so this is an excellent start.

Question pertaining to proposed implementation of SAM

RE Considering the proposed MC policy document for the implementation of the concept of SAM, do you find the document to be (yes or no, and please give reasons for your answer):
Required?

C1 yes.

RE Appropriate to private hospitals?

C1 Very definitely.

RE Factual in content?

C1 Absolutely.

RE Usable by the MC group?

C1 Very much so.

RE Do you believe that SAM MC policy document facilitated the decision process in the utilisation of a proposed monitoring requirement? Yes or no, and please give reasons for your answer

C1 Absolutely yes, because it is very practical in that we ((*referring to the Mediclinic group*)) are actually busy with such implementations at the moment. It will be successful because it is a process that we embarked upon on. So its talking to something that we are actually doing at the moment to enhance the overall, you know, pretence of what we are doing.

RE Would you apply the proposed MC policy document to implement the SAM methodology? Yes or no, and please motivate your answer

C1 Oh absolutely, without a shadow of a doubt.

RE Do you agree or disagree that the implementation of MC SAM policy would add value within MC and furthermore would this value contribution be appropriate to other related industries?

C1 Oh very definitely, I think the marriage of not only looking at the asset per se and its repair history as a decision maker or replacement tool but where we look at actual inefficiency of that machine or being able to apply better controls or enhanced controls to that equipment and a) looking at its replacement history based on ROI in terms of savings or increasing the asset life span by improving the output of that machine by using smart controls.

RE What are the strong points of the proposed SAM implementation?

C1 As I outlined in my previous answer, its very practical, it is being implemented, it is already half way there to succeeding in embedding it into Mediclinic.

RE What are the weak points of the proposed SAM implementation?

C1 I don't think there is weak points per se, it's not a question of weak points. It is one of the issues yes, that it does cost a bit of money to implement this without immediate short term gain. So it is very difficult to motivate the SCADA implementation on actual ROI methodology, one has to have a leap of faith to say - this is the system that we are, that we put faith in and then its continued in that the installation should be based or modelled on what has been achieved in the first step of the process. So we must target items that you can show, that we can do a tangible improvement. For example the one that I gave you on water consumption. (*Candidate goes on to elaborate on the value adding benefits of receiving tangible information on which to make decisions. Where this example can be used to motivate the value of implementing a SAM system.*)

RE What aspects of the proposed SAM implementation requires improvement?

C1 It is very difficult to say that it requires improvement. I think what one would very quickly see is that if there are any enhancements that can be made to the documentation, they will pop out as you go along with the implementation process and there many different users with like documents. So any technical manager or supervisor that does proceed with the implementation would be able to validate positive feedback. What we have learnt that is that, where in the beginning we thought it was a much more plug and play scenario, there are definitely intricacies. (*Candidate goes on to give an example of some technical managers struggling with implementing SCADA and that help is required. Where implementation is currently widespread. Furthermore the standards of implementation are further emphasised, where back up of the information is important and IT involvement is required.*)

RE (*Researchers shares experiences with respect to SCADA implementation at various other hospitals and how certain criteria are lost, where own interpretations are formed by technical managers or artisans within the department that influence what is measured and the critical nature is lost*)

C1 (*Candidate agrees that certain standards are required to provide a framework. Candidates goes on to further elaborate on the possibility of implementing a type of audit on SCADA equipment with a possible check sheet. Where an auditor can be used to asses certain criteria and confirm implementation of certain standards, measured across the group where a benchmark can be established. Candidate agrees that more standardisation is required within Mediclinic.*)

E.2 Candidate 2

Introductory questions

RE Do you agree to take part in this study where our conversation will be recorded for research purposes?

C2 Yes I do ((*interruption in interview*)), okay continue.

RE Have you read through the supporting documents and do you have any questions or queries?

C2 No, I've read through the document, I've read through all your documents, and I've forwarded you my comments.

RE (Researcher apologises for having to go through the document again, after comments were already sent however that the interview needs to be conducted where candidates are dealt with in the same way to capture responses to transcribe information where further analyses can be conducted for research purposes. Furthermore the candidate had queries regarding the types of assets which were utilised within the study, where the candidate did not feel the supporting document clearly specified that only assets relating to infrastructure were being addressed. Researcher clearly specified that only assets related to the infrastructure of an operating theatre was considered in this research.)

Question pertaining to the research methodology followed

RE Do you agree that an appropriate research methodology was conducted, which is relevant to the topic being investigated? Yes or no, and please give reasons for your answer

C2 Yes, yes I agree

RE In your opinion, what are the strong points of the research methodology utilised? ((*Telephone conversation is cut off, where interview to restarted. Researcher asks same question*))

C2 Mmmm, what's the strong things, well I think for starters it's nice if you have somebody taking an objective view of what actually happens in theatres. I think its fair research.

RE In your opinion, what are the weak points of the research methodology utilised?

C2 Well, from, what I read and the objectives, was that it didn't spell out that the subject was to look at theatre infrastructure (pause) because I, I thought that more should have been done on the theatre as a whole and not just on the infrastructure. (Researcher mentions equipment within the theatre where the candidate agrees that research should have included these loose individual items)

RE Considering the research methodology which was followed to investigate SAM implementation and identify critical assets within the hospital environment, what is your opinion of the potential of the SAM policy as an objective decision-making tool for assisting MCSA TM/TS's to improve PAM within the hospital environment?

C2 Ja, (pause), Charles for me that is partly one of the biggest contentious issues in that I think, personally, we are trying to put too much into programme to assist us and we kind of losing, I don't know if ability is the right word, day to day knowledge of people knowing in order for them to react. People are now not bothering to know, to go to a PC find an answer because of what something, because of what somebody programmed into it. And if I can add to that, one of my concerns is that often a programme is written for something specific and very often it's rolled out as generic and I think that that's one of the flaws, in my opinion, of programming things.

RE Please comment on the architectural aspects of the research design framework, regarding the data gathering methods and specifically the questionnaire.

C2 Well the data that you used, by and large, the previous documentation that you used was actually good. I think in terms of like the company, it be beneficial that somebody looked at the data again, which was aging, some of the data you looked at, some of the documents that you used, are like thirteen, fourteen, fifteen years old, and not necessarily reviewed.

RE Based on your previous comments, how do you think it is possible to improve the research study?

C2 Wugh, um, how can it be improved. I'll have to think about that one. I don't have my documents with me.

Question pertaining to proposed implementation of SAM

RE ((*Candidate goes on to explain the intention of the policy document as a formal process to implementing data monitoring devices in a structured approach. Where the policy highlighted feedback from previous informal discussions where the idea toward implementing monitoring devices are to plan for what and how to achieve actionable results.*))

RE Considering the proposed MC policy document for the implementation of the concept of SAM, do you find the document to be (yes or no, and please give reasons for your answer):
Required?

C2 Well, if you are going to implement SCADA then it would be good to have it a structured approach for implementation.

RE Appropriate to private hospitals?

C2 Well, if you're going to do anything, it is appropriate for any industry to do a structure; to put in things rather structured approach.

RE Factual in content?

C2 ((Long Pause)) I think so.

RE Usable by the MC group?

C2 I had my reservations but I am not a PC person, all right, so from the perspective from where I come, it is difficult for me to say that this is the way ((emphasis on the way forward)). I certainly believe that it could add value. And I want to add, also, I don't think one can discount the new work force coming in and their education, their way of thinking, is in that direction, its something that you cant stop.

RE Do you believe that SAM MC policy document facilitated the decision process in the utilisation of a proposed monitoring requirement? Yes or no, and please give reasons for your answer

C2 No.

RE Would you apply the proposed MC policy document to implement the SAM methodology? Yes or no, and please motivate your answer

C2 I have my reservations on that.

RE Do you agree or disagree that the implementation of MC SAM policy would add value within MC and furthermore would this value contribution be appropriate to other related industries?

C2 Again, like I said I think you're looking for a yes no and I'm saying that it is in between.

RE What are the strong points of the proposed SAM implementation?

C2 The strong things of the proposal, is, in my opinion, only going to work for the new work force, for the future work force, I mean it could be because of their thinking methodology.

RE What are the weak points of the proposed SAM implementation?

C2 In my opinion, the weak point of it is you actually dis-empowering the individual from knowing rather than reading. In the past people used to need to know things, like decisions, the modern thinking is you need to know where to find the information. You don't need to know it.

RE What aspects of the proposed SAM implementation requires improvement?

C2 ((Long pause)) I would've like to have seen the smart asset management proposal, I think it should be dated with peoples current way of doing things. Also, and I think had it been something between the two, I think at the moment its too extreme. In, my kind of way of thinking I want the individual to know it all, and in this instance, with programming everything into a system to give you answers, so there must be something in between cause I don't believe that SCADA is the full answer for asset monitoring. It is something in between.

RE ((*Researcher goes on to explain that the idea of the document is not to make SCADA the complete solution, but rather utilise smart monitoring systems such as SCADA as a supporting structure to current way of doing things. Where existing documentation is emphasised in the policy document and the SAM is an addition to current way of conducting work*)).

C2 ((*Candidate agrees, further specifics that existing document should rather be taken where changes should be noted as required to existing operational management document. This document requires an update where in the view of utilising SAM, current planned maintenance instruction are in place this needs to be kept up to date. Candidate shares that the original operational management*

document was written with a view of a manual job card system, where currently hospitals are utilising PC's to create job cards. Additionally what needs to be taken into consideration is to factor in the mobility of the system, where taking CMMS to the asset is a possibility. This is useful where additional information is required, such as reading more information like usage and detecting abnormalities and integrating that within CMMS to create specific notifications.))

RE ((*Researcher emphasises that this concepts are being addressed within the research, where the aim of this document is to create a baseline of SAM and SCADA implementation.*))

C2 ((*Candidate emphasis that the baseline should be from current documents which need to be reviewed, utilsing a reviewing tool.*))

E.3 Candidate 3

Introductory questions

RE Do you agree to take part in this study where our conversation will be recorded for research purposes?

C3 Ja, no problem

RE Have you read through the supporting documents and do you have any questions or queries?

C3 ((*Candidate did indicate before the interview that certain concepts within the research are difficult to grasp where, candidate offered to either have an initial discussion or address certain points with the questions set forward. It was agreed that questions could be put forward during the questionnaire.*))
Yep, no problem.

Question pertaining to the research methodology followed

RE Do you agree that an appropriate research methodology was conducted, which is relevant to the topic being investigated? Yes or no, and please give reasons for your answer

C3 ((*Question was put forward to the researcher weather the research conducted only considered the questionnaire or the entirety of the research. Researcher commented that the processes as put forward in the documentation provided, describing the entire process should be taken into account.*))
Um, ja, well I'm very familiar with that type of research methodology and I've mastered it before so I understand it and yes I agree with it. Put to use in this content in ja, yes I agree with the methodology, I don't have issues with that.

RE In your opinion, what are the strong points of the research methodology utilised?

C3 Well, it depends on your comprehensiveness in the research but the strong point by using a qualitative method, you and also using open-ended questions, you know there's the potential to allow previously un-thought of or you know you, new unexpected issues to be highlighted you know or, I don't know, to be open-ended but its completely open I would say.

RE In your opinion, what are the weak points of the research methodology utilised?

C3 I think the weak points can possibly be, I don't know if this counts, but Smart Asset Management has got, the very questionnaire throughout, I, its a very academic approach and I, with the amount of time required to get a 100% just of what you're doing I wonder if the technical managers are, you know, fully understand and, I'm, some of them potentially get lost in the romance of Smart Asset Management. And there and all the potential benefits and I just ja, the answering thereof I would, me personally, I would assume that, along the questions obviously thinking that the technical manager were answering within romantic notions rather than actually well properly analysing it.

RE Considering the research methodology which was followed to investigate SAM implementation and identify critical assets within the hospital environment, what is your opinion of the potential of the SAM policy as an objective decision-making tool for assisting MCSA TM/TS's to improve PAM within the hospital environment?

C3 The potential of that stand in there's potential, definitely and I think it is an arena has to be addressed if the quality is put together. I don't think it is very realistic, I don't, in the current format I, its, I don't think its appropriate for where we are. I think it is very academic and um very, very ((laughs)) how can I put it, you have to, you have to read it a couple of times, to fully understand it, it addresses a very basic principle, but where, in our operational environment we are generally very much simple and we are keeping it very practical more than academic and so there is a lot of stuff there that are probably exclude in it, perhaps maybe ja, maybe remaining the guideline its, in the end of the day and perhaps we could say very fine level in the foundation in the guideline. About that policy is that I find it, short of how to go about implementing asset management system and there are some practical things that are mentioned in there but I find the biggest problem with the SAM, again to use that word as a romantic notion of it that we are monitoring assets for a priority for example generators, UPS all the different pieces of equipment and you then you mix it all up. And you can remote view it and log certain things. But I just question what happens to it all, how do people react to it or define it and what is it actually they need to be monitoring, what are the real focus points and if you keep it down to that, the policy is left pretty much open. If one technical manager wants to measure emergency water systems for example, where you mentioned it under cold water reticulation. You can measure incoming pressure, water levels and the pump whether its running and in auto, if it is reaching pressure, what pressure is it peaking to, how many litres per minute is flowing you know, you could really go to town. You

could say the only real thing that I'm interested in the emergency water level and monitoring it to see where you are (referring to the water level), that it is lasting. I feel that it is very open in that document. We are going to have technical managers going way overboard, and some who are technically impaired.

RE Please comment on the architectural aspects of the research design framework, regarding the data gathering methods and specifically the questionnaire.

C3 ((*Question put forward by the candidate asking if the data gathering methods only involved the survey questionnaire. Researcher indicated that CMMS data was also utilised where the candidate commented that this was not made clear enough in the supporting document. Candidate agrees that by adding CMMS data this improves the research quality however feels that personally the candidate can not contribute much value to this question.*))

RE Based on your previous comments, how do you think it is possible to improve the research study?

C3 I would be saying that, I gather how you would go about actually evaluating real value adding as part of the SAM, is really value adding in the AM. ((*Candidate goes on to discuss his interpretation of asset management compared to maintenance. Where he feels that the maintenance aspect is not necessarily included in his interpretation of SAM. Candidate further refers to SAM as more involved with monitoring the asset life, and performance where the aspect he does not see the inclusion of maintenance within SAM*))

RE ((*Researcher goes on to further discuss the concept of AM vs PAM, where maintenance is an aspect of PAM as per the definitions provided with the supporting documents. SAM according to the researcher is an additional aspect within the PAM realm where the concept of SAM is to gather information to be able to make more informed decisions based on PAM methodology. The researcher also address the fact that currently no policy is in place within Mediclinic where the researchers personal view is that no restrictions are currently in place and technical managers are open to their own interpretation of what is required. Where the intention of the policy document is aimed at creating a baseline of what is required and how to go about implementing SAM, where policy document is a supporting tool to existing maintenance strategies within Mediclinic.*))

C3 ((*Candidate goes on to discuss whether the intention of the document is to prescribe what should be measured*))

RE ((*Researcher explains that intention is not to be too prescriptive, but rather to provide clarity on what is identified critical and furthermore what constitutes a baseline of critical assets which should be monitored*))

C3 ((*Candidate goes on to discuss the concept of resource monitoring as definite value adding tool. Candidate further enquires whether this concept falls under AM*))

RE ((*Researcher agrees that resource monitoring is an important factor which is also encompassed within AM, however explains focus of the study as pertaining to specifically asset infrastructure which is critical to supporting operating theatres. Researcher continues with questioning*))

Question pertaining to proposed implementation of SAM

RE Considering the proposed MC policy document for the implementation of the concept of SAM, do you find the document to be (yes or no, and please give reasons for your answer):
Required?

C3 yes, it is required.

RE Appropriate to private hospitals?

C3 I am not sure, that question is a bit odd to me. Why specifically to a private hospitals. ((*researcher indicates, if question is applied to all hospitals*))
Yes ja definitely.

RE Factual in content?

C3 Yes no problem.

RE Usable by the MC group?

C3 In its current state, I would ((pause)), it's usable yes, it definitely usable by the Mediclinic group but I would be strongly suggesting that there are certain changes mentioned, that it needs to be a little bit more, less broad. A little bit more specific.

RE Do you believe that SAM MC policy document facilitated the decision process in the utilisation of a proposed monitoring requirement? Yes or no, and please give reasons for your answer

C3 I would be wanting to say no. The policy is a very broad overview of SAM, but in terms of facilitating in a decision making process and the utilisation, I don't know. ((*Candidate discusses the challenges within the group concerning the possible implementation of such a document, where currently various regions are at different phases doing at their own pace.*)) It does help to a certain degree, but I feel it does not have enough direction.

RE Would you apply the proposed MC policy document to implement the SAM methodology? Yes or no, and please motivate your answer

C3 Not in its current form, no.

RE Do you agree or disagree that the implementation of MC SAM policy would add value within MC and furthermore would this value contribution be appropriate to other related industries?

C3 I agree for a start, it does add value but I believe that it is in it's infancy. You are starting to put structure with this document, you would starting to structure and formality to something that is largely gone rouge at the moment, and so I see it as the beginning of and will probably go through may iterations and it will be bold. Yes implementing a user policy it would add value.

RE What are the strong points of the proposed SAM implementation?

C3 The strong points is that it starts to give an overview and insight especially those that are a little bit more in the outlying areas, that perhaps haven't encountered this stuff before will hopefully make them think ((*candidate elaborates that it may be too academic for certain people to understand however continues conversation*)). It give a nice overview of what the purpose of SAM is about and give areas in which to start focusing on, you know how to go about it. ((*Candidate continues to confirm that this planning should be done with regional managers, on how to go forward in focusing the SAM implementation within the group*))

RE What are the weak points of the proposed SAM implementation?

C3 It is very academic.

RE What aspects of the proposed SAM implementation requires improvement?

C3 I don't know, I would be wanting to see that it, within the future, that it would perhaps detail a little bit more specifics about the details that would genuinely add value, I am a great believer in that if something doesn't work on paper its not going to work on a computer. (Candidate goes no to give an example about strategic check, if not done correctly on paper it will not add value by doing it on a computer.) It's about really trying to identify what adds value. ((*Candidate goes on to discuss how proving the value contribution will justify and ROI where other regions are far ahead in terms of having information in order to justify the implementation of monitoring devices. Where other hospitals will struggle to justify SAM within their budget*))

RE ((*Further discussions on standardisation of software where currently various critical asset come with their own monitoring software however currently these devices are not able to be integrated to a standard platform and interface to utilise a specific policy. Where researcher suggests the policy being implemented as far procurement of new assets and specify what is required form the newly purchased asset in terms of SAM*))

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